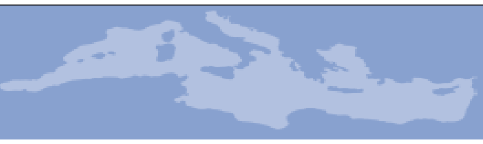
Supporting Green Entrepreneurs for a POPs free Mediterranean

Module on:

Green Entrepreneurship and Hazardous Chemicals Substitution Process



Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC)
Mediterranean Action Plan

Regional Activity Centre for Sustainable Consumption and Production

UNEP

MAP

STOCKHOLM CONVENTION

GOBIERNO DE ESPAÑA
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The SCP/RAC, based in Barcelona-Spain, was established in 1996. Its mission is to promote sustainable consumption and production in Mediterranean countries. The SCP/RAC activities are approved by the Contracting Parties to the Barcelona Convention and by the Bilateral Monitoring Commission made up of representatives from the Spanish and Catalan Governments.

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AUTHORS AND ACKNOWLEDGEMENT

Supervision and Coordination:

Francesca Culcasi, Regional Activity Center for Sustainable Consumption and Production

Work team:

This module has been drawn up by ISTAS's experts Sara Perez Diaz and Maria Purificación Moran Barrero (Union Institute of Work, Environment and Health) and Amit Paul founder of Paxymer® and the collaboration of Frederic Gallo (senior expert at SCP/RAC)

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Introduction

"Substitution is a preferred risk reduction strategy in environmental policy and in workers' health and safety legislation. Replacing harmful substances and processes with less harmful ones or with nonchemical alternatives is widely acknowledged as a very effective strategy to reduce, minimize, or even eliminate risks. Additionally, substitution of dangerous chemicals with less dangerous ones is recognized as an optimal way to overcome the difficulties of complex chemicals regulations"[1].

The ***Stockholm Convention[2] on Persistent Organic Pollutants*** **(POPs)** is a global treaty which entered into force in 2004 to protect human health and the environment from chemicals that remain intact for long periods, become widely distributed geographically and accumulate in the tissue of humans and wildlife. Exposure to POPs can lead to serious health effects like cancer, birth defects, dysfunction of hormonal systems and other health problems. Given the persistence of these substances, they are also transported over large areas, and the problem with POPs is recognized as a global problem.

Substitution, development and use of alternatives to POPs are mentioned several times in the Stockholm Convention on Persistent Organic Pollutants. In the preamble it is stated that the parties of this convention recognize the importance of developing and using environmentally sound alternative processes and chemicals.

The Stockholm Convention also encourages the substitution process with different recommendations:

- ✓ Development and usage of substitutes or modified products and materials should be promoted.
- ✓ Appropriate research, development and monitoring of POPs and there alternatives should be encouraged.
- ✓ Information on POPs and their alternatives should be provided; exchange of information of alternatives should be facilitated.
- ✓ When considering alternatives to POPs, also socio-economic factors should be taken into account.

As Regional Center for the Stockholm Convention, one of the main priorities of SCP/RAC[3] in its mandate to promote sustainable consumption and production is to support companies and entrepreneurs, in the phasing out of POPs and the use of alternatives to toxic chemicals in the design and production of products and/or services.

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[1] Lissner L., Romano D. "Substitution for hazardous chemicals on an international level – The approach of the European project SUBSPORT" - www.istas.ccoo.es/descargas/kk6771725575236w.pdf

[2] ttp://www.unep.org/chemicalsandwaste/UNEPsWork/PersistentOrganicPollutantsPOPs/tabid/296/Default.aspx

[3] http://www.cprac.org/en/about-us/scp/rac

Specifically, SCPRAC aims at contributing to the replacement of toxic chemicals by sustainable alternatives in the whole cycle of products and goods, mainstreaming toxic chemicals free products and services in the market and informing and training businesses and citizens on the existence of alternatives to those chemicals are key measure to effectively prevent them from the source.

Based on the above, this module aims to support companies in implementing a substitution process of hazardous chemicals, as well as being a resource for other stakeholders such as authorities, environmental and consumer organizations, and scientific institutions.

Experts from **ISTAS**[4] (Union Institute of Work, Environment and Health), based on the European Project SUBSPORT[5] training methodology will explain what the substitution definition is, how to identify hazardous substances, where to search and how to compare alternatives, how to design free toxic processes and products and how to do a cost assessment. Besides, thanks to the relevant contribution of the **Paxymer®**[6] founder (the green flame retardant system), real detoxed business cases will outline the rationale for undertaking a substitution process, and to define the parameters and management factors involved in the process itself. The selected cases, will also guide the users to know which are the potential challenges/barriers addressed by the entrepreneur, the way he/she tackles them and the solutions/alternatives needed.

It is important to mention that this module has been thought to be integrated into the existing methodology on *Green Entrepreneurship and Eco-Design* that SCPRAC has elaborated with the intention to provide users (entrepreneurs, women, senior students, etc…), with a structural guide on how to create a strong business plan that highlights not only the economic potential of enterprises, but also the environmental and social benefits it will create. Therefore, should you be interested in reading or using it, you can find it at the following link: http://www.cprac.org/en/media/studies/methodological-manuals

[4] http://istas.net/web/index.asp?idpagina=2982

[5] http://www.subsport.eu/

[6] http://paxymer.se/

1. The substitution process

1.1 Definition of substitution

A requirement for any discussion on substitution and its key factors is a broadly accepted understanding of what substitution is. The term "substitution" is used in legal documents, but is hardly ever precisely defined in practical and policy terms. Some examples of definitions by various stakeholders illustrate the differences:

> Substitution is "*...the replacement of one substance by another with the aim of achieving a lower level of risk.*"
>
> European Chemical Industry Association (CEFIC)[7]

> "*The Principle of Substitution states that hazardous chemicals should be systematically substituted by less hazardous alternatives or preferably alternatives for which no hazards can be identified.*"
>
> Greenpeace[8]

> *1. The employer shall ensure that the risk from a hazardous chemical agent to the safety and health of workers at work is eliminated or reduced to a minimum.*
> *2. In applying paragraph 1, substitution shall by preference be undertaken, whereby the employer shall avoid the use of a hazardous chemical agent by replacing it with a chemical agent or process which, under its condition of use, is not hazardous or less hazardous to workers' safety and health, as the case may be.*
>
> EU COUNCIL DIRECTIVE 98/24/EC of 7 of April 1998.[9]

> "*… the replacement or reduction of hazardous substances in products and processes by less hazardous or non-hazardous substances, or by achieving an equivalent functionality via technological or organisational measures.*"
>
> Lohse/Lissner (2003)[10]

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[7] CEFIC. Paper on Substitution and Authorisation under REACH, 23. May 2005, Summary, http://www.cefic.be

[8] Greenpeace. *Safer Chemicals within Reach - Using the Substitution Principle to drive Green Chemistry*. Amsterdam: 2005, Greenpeace International.

[9] Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)". Official Journal of the European Communities L 131 (1998): 11-23.9.

[10] Lohse, J., Lissner, L., *Substitution of hazardous chemicals in products and processes*, Report compiled for the Directorate General Environment, This study is available on the website of DG Environment (May 2006) under: http://ec.europa.eu/environment/chemicals/pdf/substitution_chemicals.pdf (accessed March 2013).

1.2 Substitution Steps

1. **Define the Problem**

Identify what you need to substitute and why. Prioritize substitution considering applicable legislation, policies of your company and interests of other relevant stakeholders (customers, public etc).

Describe both hazards and useful properties of each candidate to substitution, as regards the application considered. Ask your suppliers and/or use reliable sources to check hazards. Describe the function of the substance and analyse the production process. It is important to have a broad view of the function of the substance so you may find not only alternative substances, but also alternative processes or even organisational changes that might avoid the need to use chemicals at all:

- ✓ What is the chemical/product used for?
- ✓ How does it work?
- ✓ What tasks is it used in?
- ✓ Why is it done that way?
- ✓ What are the risks it implies?
- ✓ Can tasks be performed differently? If so, what would happen?
- ✓ What do I use this product for? How does the product work?
- ✓ Can I use another product? If so, what would happen?
- ✓ Could we use other tools or technologies? If so, what would happen?

2. **Set substitution criteria**

Set preliminary criteria to eliminate alternatives that are not safer or not safe enough. When establishing criteria check what substances are on a priority/'black list' of legal bodies or companies or see which of the hazards you have identified were used by others in defining substances of concern.

Preliminary criteria will help eliminate unsuitable alternatives at an early stage and thus avoid useless efforts when searching independently or when asking for help.

3. **Search for alternatives**

Search on internet, ask authorities, professional associations, NGOs and trade unions. Look for alternatives already elaborated and implemented, this may lower the innovation costs and risks. You may also ask your supplier to formulate a safer alternative. But first, search within your own company.

4. **Assess and compare alternatives**

This phase includes presenting all the alternatives found, comparing and assessing their usefulness, applicability and safety. The following aspects must be assessed:

- ✓ **Environmental and health and safety impact:**
  this is an important first step since the driver of substitution is to get rid of hazardous substances; it is a key issue to assure that the alternative is actually safer for health and environment.
- ✓ **Technical viability:**
  assessing the functionality of alternatives to grant that they equal or excel the products they substitute. This includes research by the R&D department, detailed technical examination by users and market analysis.
- ✓ **Economic viability:**
  it must include a cost assessment and a cost/benefit analysis. Alternatives can sometimes be rejected when they imply a higher purchase cost, but it is necessary to include all costs and benefits associated with the product.
- ✓ **Social impact:**
  it involves the impact of an alternative product on other workers, human rights, society, etc. The most used system is based on the assessment of corporate responsibility through the Global Reporting Initiative (GRI).

5. **Experiment on pilot**

First try substitution on a smaller, pilot scale. Plan the technological and organisational changes needed. Pre-evaluate risks with an appropriate methodology. Assess substitution as regards functional performance, impact on workers, environment or consumers. Pay special attention to possible shift of risks and the necessary control measures. Consult with the employees.

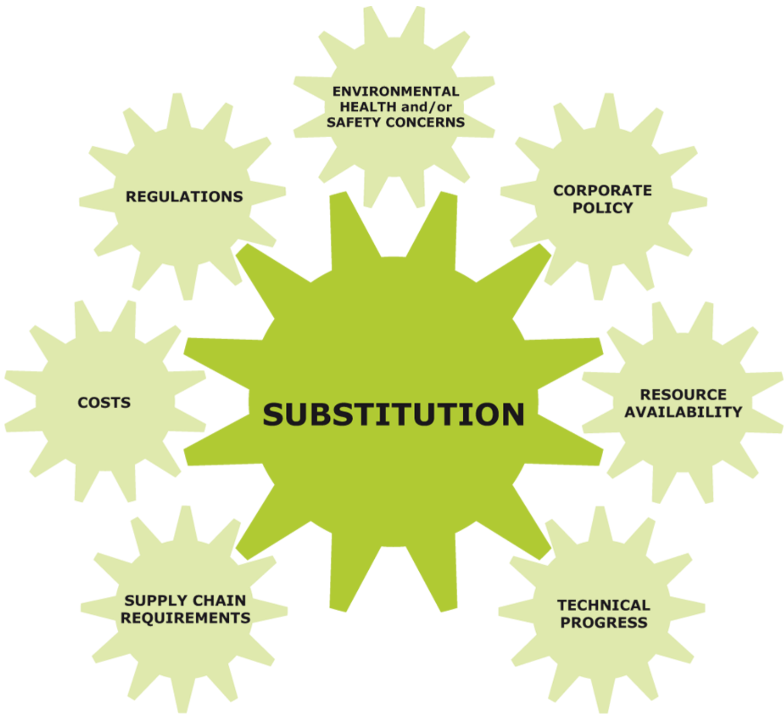
6. **Implement and improve**

Think what other measures would be needed when implementing substitution at full capacity. Re-examine the risk assessment and the health, safety and environmental protection measures. Update your supply chain and inform your downstream users. Collect extended feedback from workers and clients. Identify points to improve. Make known your achievements.

1.3 Drivers for substitution

Although legislation enforcement is recognized by companies as the main driver, other factors contribute as well to substitution such as: suppliers' knowledge, management commitment, supply chain requirements, workers and environment protection costs, public pressure or workers' pressure, among others.

Figure 1. Substitution drivers



Source: SUBSPORT, Substitution Support Portal

For small and medium-size companies/enterprises (SMEs) with very limited knowledge and information about chemicals, supplier assistance is an important factor. However, in general, only specialized suppliers (e.g. of hair dyes or disinfectants) have the necessary knowledge to provide their customers with safer products and very often only producers have this knowledge. This substitution process led by suppliers is a common model in supplier-client arrangements where users have poor or no information on chemicals.

Substitution led by chemicals users can be found in many multinational corporations, e.g. in electronics manufacturing and consumer products industry (ABB, Boots, Marks & Spencer, EUREAU, Scania, IKEA, Skanska, Heidelberger, Bosch Siemens, NCC or Volvo Technologies). Large players (large in respect to their sector's specific market power) develop substitution programmes and policies and compel their suppliers to ban or reduce certain hazardous chemicals.

Large companies that cooperate with other companies (including SMEs) and with the public sector on a regular basis (e.g. construction companies) have developed strategic approaches to avoid hazardous substances. The reasons for this are, on one hand the protection of workers, and on the other avoiding additional costs for extensive health and safety and environmental protection.

Large companies also tend to avoid incidents or critics that might affect their public reputation.

Companies producing consumer goods seem to be highly vulnerable to critics and have introduced strict rules to ban or reduce hazardous chemicals, for example in sportswear and shoes, furniture and clothes (Nike, Adidas, H&M).

Another example is when several companies act together to find solutions for a specific substitution. USA Design for the Environment programme hosts a few “partnerships” to find alternatives for specific uses, involving manufacturing companies, users and consumers or environmental organisations. One example is the BPA (bisphenol A[11]) Alternatives in Thermal Paper Partnership.

The pressure of safety representatives and trade unions has also forced companies to substitute hazardous substances that cause occupational health problems. Several examples can be found in companies that used asbestos[12] or other carcinogens.

In addition, with the progress of REACH[13] Regulation more information on hazardous effects of chemicals will be publicly available, and therefore it might become an important driver for future substitution processes.

1.4 Stakeholders in substitution

There are also different stakeholders involved in the substitution processes and each one has their own interests and drivers to carry them out.

[11] Bisphenol A, is a synthetic compound employed to make certain plastics and epoxi resins. It is considered a very hazardous substance because is an endocrine disrupter, sensitizer and toxic for reproduction.

[12] Asbestos is a group of silicate minerals with thin fibrous crystals. It is very dangerous because carcinogenic and forbidden in many countries.

[13] Registration, Evaluation, restriction and Authorisation of Chemicals a 2007 EU Regulation for Chemicals aims to assure that the risks from Substances of Very High Concern are properly controlled and that these substances are progressively replaced by suitable alternatives while ensuring the good functioning of the EU internal market. http://echa.europa.eu/regulations/reach

Figure 2. Stakeholders involved in substitution in a company

Source: SUBSPORT, Substitution Support Portal

They all play a significant and necessary role to accomplish a substitution process successfully.

Consumers deserve a special mention since they can actually put significant pressure on companies, especially in countries with lax regulatory standards on toxic chemicals.

NGOs have led several campaigns aimed particularly at raising consumers' awareness and influence them to choose non-toxic products. Good examples of such activities are the Greenpeace's Non-Toxic Shopping Guide, and different campaigns to persuade companies to avoid hazardous chemicals, especially in the textile, electronic and toy industries.

All partners involved must support substitution processes and it is essential for them to cooperate and lead joint substitution efforts.

1.5 Material substitution in practice

There are several reasons for material substitution projects to take place. All though theory would suggest that substitution is the ambition to further improve or remove the hazard profile of solutions, the normal case in the industry is that these aspects are an added benefit.

Cost savings, a new product launch, marketing potential, new legislation or pressure from stakeholders are normally additional drivers that have to be in place for substitution implementation. If the only function in a company involved is environment it is not uncommon that development projects remain development projects and do not get rolled out into the rest of the business.

The following case will show a successful substitution example; starting with the case's description we will then use the frameworks provided previously in the chapter to analyse pressure and benefits from the customer side.

The selected case, is represented by one of biggest companies in the world which is active in a number of industries: personal safety and protective gear is one of them. The company has implemented an alternative solution for flame retardant polyolefin plastics thanks to the Paxymer® 's technical support and partnership.

Figure 3: Business case: Material substitution in Welding helmets – overview

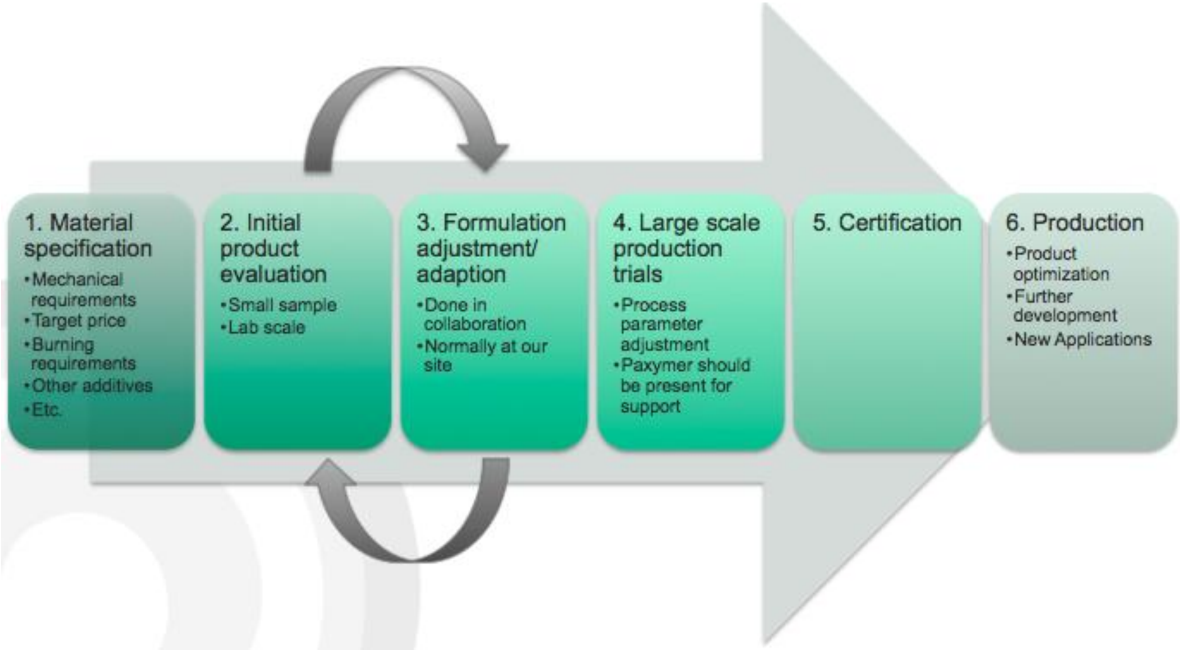
Situation	• New material development initiative with customer. • All investments were made apart from the flame retardant.
Challenges	• Meeting material specification • Meeting the fire specification • Finding a halogen-free solution
Actions	• Involvement in development • Joint effort between OEM, Paxymer and subcontractor • Adaption of formulation the specific customer demands
Results	• Worldwide product launch • New low-cost position for the customer on the market

The company started a development project for material substitution in one of their welding helmet series. The ambition was to introduce a product on the low cost market. They had chosen cheaper raw materials and had made necessary adjustment to the process and tooling. However in functional testing it turned out that the fire performance was not satisfactory.

This was initially regarded as a minor issue but as they tested different alternatives and failed to meet the specification it turned out to be a major technical challenge. Mainly due to that all other parameters were fixed – tooling, manufacturing process, material, design etc - and they needed to find a material that would fit into that set frame of made investments.

Flame retardants for plastics, are not compatible per se with the plastic itself; this means that in genaral, properties of the base material will deteriorate in meeting fire standards. In this case, it was impact resistance and processing properties that were the main challenges.

Figure 3: Paxymer® 's sales process



The above sales process represents the one applied by Paxymer® to the selected company. The first phase of the process required a material specification, initial small scale evaluation at customer and formulation is iterated before going to production scale testing, certification of the final material from a fire and functional point of view and then the customer will buy commercial quantities and start marketing the product.

The process typically takes from 6 months to several years depending on the customer.In this case, the substitution process took 6 months to be implemented – today the product is being sold worldwide.

Analysing the case from the substitution drivers using the frame work for substitution we can see that the case fulfils many of the drivers:

- ✓ Corporate policy: The company has a policy not to use hazardous chemicals and were limited to stay away from brominated compounds[14].
- ✓ Resource availability: entry point was an established relationship with the development department of the company which put Paxymer® on the map as a technical alternative.
- ✓ Technical progress: fire, mechanical and processing properties were met.
- ✓ Supply chain requirements: The company was the main driver in the process for substitution. The solution met processing requirements sufficiently.

[14] Bromine is a common flame retardant that is under heavy scrutiny due to proven persistence, bio-accumulating and toxic properties of some compounds.

- ✓ Costs: The company had selected a low cost profile and switched from Polyamide to a Polypropylene (one third of the cost) some of this advantage disappeared by including FR, savings were still significant.
- ✓ Regulations: No external regulation. It was driven by company policy.
- ✓ Environmental, health and safety concerns: Inclusion of the fire safety system was necessary for the product to meet the demands and the corporate policy of avoiding hazardous chemicals were driving factors in this case.

The stakeholder analysis shows that the company was the main driver in this case. Their ambition to launch a new product on the market to broaden their prodocut range, was already fully decided in the organisation. This explains the speed of the project – the timeline was only 6 months from material specification to implementation of final product on the market.

Conclusions

The framework is useful for analyzing drivers for substitution after the fact. But mainly it is useful as a tool to formulate your pitch – it encompasses many of the important aspectes of a projetc and may highlight overlooked benefits to the customer. It is however easy to discard such an analysis since many of the drivers are unknown and unclear in the beginning of a project – but analysing the situation using the framework may give additional insights into benefits that the customer has overlooked, information that is still missing or shift the focus of the pitch to prioritize the more urgent of the customer's pains.

2. Green entrepreneurship and Free Toxic Chemicals

2.1 Rationale and opportunities

Current methods of economic development are no longer sustainable. Sources of raw material are being rapidly depleted and a significant amount of energy is wasted in production processes. Human health and the environment are exposed to a considerable amount of polluting agents during manufacture and disposal.

The health effects of this industrial model are still unknown, according to the World Health Organization (WHO), the number of deaths caused by environmental exposure and the handling of chemicals reached 4.9 million people in 2004.

An estimated 2.34 million people die each year from work-related accidents and diseases. Of these, the vast majority -an estimated 2.02 million- die from a wide range of work-related diseases. Of the estimated 6,300 work-related deaths that occur every day, 5500 are caused by various types of working related diseases.

Technological, social and organizational changes in the workplace brought by rapid globalization have been accompanied by emerging risks and new challenges.

Though some traditional risks have declined thanks to improved safety, technological advances and better regulation, they continue to take an unacceptably heavy toll on workers' health[15].On the other hand new technologies, such as nanotechnologies and certain biotechnologies, pose new and unidentified hazards in the workplace.

Based on the above, new initiatives and projects have been promoted recently which seek to increase business profitability and raise social awareness about the health consequences of industrial activity for workers and citizens, as well as the efficiency of resources, focusing on the more sustainable ones. Some examples of them follow.

The European Commission (EC) has launched the resource-efficient Europe – Flagship initiative of the Europe 2020 Strategy.The flagship initiative supports the shift towards a resource-efficient, low-carbon economy to achieve sustainable growth[16].

Likewise, the EC has also adopted the Communication "Towards a circular economy: a zero waste programme for Europe"[17] and annex to establish a common and coherent EU framework to promote the circular economy.

Turning Europe into a more sustainable and circular economy means:

- ✓ boosting recycling and preventing the loss of valuable materials;
- ✓ creating jobs and economic growth;

[15] ILO. The prevention of occupational diseases available on: http://www.ilo.org/safework/info/publications/WCMS_208226/lang--en/index.htm

[16]More information in http://ec.europa.eu/environment/basics/green-economy/efficiency/index_es.htm

[17]Circular Economy http://ec.europa.eu/environment/circular-economy/

- ✓ showing how new business models, eco-design and industrial symbiosis can move us towards zero-waste;
- ✓ reducing greenhouse emissions and environmental impacts.

Based on the above, we can state that *Green Entrepreneurship* is considered as one of the main engines playing a relevant role within the complex systemic process enabling a more Sustainable and Circular Economy and its key drivers, here called *green entrepreneurs,* are those who accelerate the transition anytime they convert their ideas into feasible and viable projects.

Green entrepreneurship from an industrial perspective

Scanning through the Wikipedia entry of entrepreneurship one will find that the definition consists of a number of criteria: opportunity, innovation, initiative, leadership, management, risk, and uncertainty. An entrepreneur is defined as a person willing to deal with risk and uncertainty in order to utilize an opportunity, show leadership and solve a problem through innovation and initiative.

One of the first definitions by Richard Cantillon coined in the 18th century was the view of the entrepreneur as a "risk taker who will exploit opportunities to maximize financial returns".[18] All though this definition still has some merit the increasingly complex global and business context has provided for exploitation of opportunities that provide far more value than a mere maximisation of financial returns.

The technological innovation that resulted in **Paxymer®** ® came about as a response to a technological challenge driven by an ambition to improve environmental and health performance of a group of products. The invention and the company built around it is solidly founded on the idea that it would like to improve the performance of these products by implementing it's solutions – this is what sets green entrepreneurship apart from the "traditional" entrepreneurship, the alternate mission statement that limits the possibility for opportunism. The scope of the innovation is not merely maximisation of financial returns but the very basis for the company or ventures existence is to improve a social, environmental or health condition.

One of the most critical aspects of entrepreneurship and growth businesses is timing. Entrepreneurs during the 19th century industrial revolution had it, the Internet boom entrepreneurs in the beginning of the 21st century had it and we are currently in the early cycle within the business of greening industries, Cleantech or green entrepreneurship.

Green entrepreneurship is entrepreneurship with added restrictions – it is however a natural evolution, a response to the need for innovations that encompass the bigger societal issues we are facing. Rather than green entrepreneurship one might talk of entrepreneurship within a market where the major opportunities are within Cleantech or greening of the industries. Solutions that address environmental issues, chemicals substitution or energy efficiency is on the agenda because the field shows promise and technologies and legislation are converging. The scale of this opportunity is vast – rather than comparing it to the Internet boom we believe that the relevant comparison would be the first industrial revolution. That comparison in turn might also give you an idea of

[18] Available online: http://en.wikipedia.org/wiki/Entrepreneurship

the resistance that existing industries will put up: Green entrepreneurship is not about moving existing business ideas to a new venue.

Green entrepreneurship is at the core what Schumpeter[19] called "creative destruction" – new industrial solutions, rethinking industrial processes and business ideas in the light of the new knowledge and new technologies. It puts demands on people to integrate many different fields in order to create products that work with new production systems and automation as well as meet the latest legislation. It is the only lasting form of entrepreneurship in the transparent, globalized world we are developing into, and it is turning out to be a fantastic business opportunity.

Likewise, as any entrepreneurship relying on productive investment these projects have an impact on the labour market's offers and demands. The development of these processes influences economic activity and employment.

As a matter of fact, the European Commission presented this year a Communication on a Green Employment Initiative: tapping into the job creation potential of the green economy[20] .

Maintaining the same line of terms we will now refer to green jobs.

"Green jobs"

The International Labour Organization (ILO)[21] defines jobs as green when they help reduce negative environmental impact, ultimately leading to environmentally, economically and socially sustainable enterprises and economies. More precisely, green jobs are defined as decent jobs that:

- ✓ reduce consumption of energy and raw materials
- ✓ limit greenhouse gas emissions
- ✓ minimize waste and pollution
- ✓ protect and restore ecosystems

Green jobs are among the fastest growing jobs in the EU, that raised even during the current economic crisis (20% increase between 2007 and 2012). These jobs grew from 3 million to 4.2 million in the period between 2002 and 2011. The European Commission estimates the creation of 20 million green jobs by 2020.

Green jobs include activities that reduce environmental impact in companies and economic sectors to the point of achieving sustainable levels of production.

It is clear that compared to other sectors (agriculture, energy, construction etc...) the intensive energy industries (chemical industry, iron, steel) face a more complex situation

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[19] Creative Destruction, Capitalism, Socialism and Democracy (New York: Harper, 1975) [orig. pub. 1942], pp. 82-85:

[20] Available on http://ec.europa.eu/transparency/regdoc/rep/1/2014/EN/1-2014-446-EN-F1-1.Pdf

[21] http://www.ilo.org/global/topics/green-jobs/news/WCMS_220248/lang--en/index.htm

since they are expected to cope with challenges and seize new opportunities associated with the mitigation of GHG emissions and the development of new sectors and products.

Nevertheless, basic industries, i.e. those that provide necessary supplies to sectors as construction, energy, manufacturing industries, should also be considered as sectors that contribute to sustainability through recycling and reuse of resources as paper, heavy metals, etc...

Furthermore, technology or process innovation can also eliminate or reduce the environmental impact of traditionally products/processes. In this regard, it is important to point out the so called ***"Green Chemistry".***

"Green Chemistry"

Green Chemistry is a valid alternative for entrepreneurs that explore new business options. Green Chemistry is based upon the application of a series of principles to reduce the use or generation of hazardous chemicals during the design, manufacture of application of chemical products.

Sustainable and green chemistry in very simple terms, is just a different way of thinking about how chemistry and chemical engineering can be done. Over the years different principles have been proposed that can be used when thinking about the design, development and implementation of chemical products and processes. These principles enable scientists and engineers to protect and benefit the economy, people and the planet by finding creative and innovative ways to reduce waste, conserve energy, and discover replacements for hazardous substances.

It's important to note that the scope of these of green chemistry and engineering principles go beyond concerns over hazards from chemical toxicity and include energy conservation, waste reduction, and life cycle considerations such as the use of more sustainable or renewable feedstocks and designing for end of life or the final disposition of the product.[22]

[22] American Quimical Society definition. http://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/definition.html

2.2 Detoxed business models

The two following cases, are included in the data base of the EU substitution project SUBSPORT[23]; they are examples showing how entrepreneurship aims at creating driving strategies to achieve social, environmental and economic business solutions.

1- Example of a transition to a cleaner technology in a laundry shop

Situation:

Laundries and dry cleaning shops generally use hazardous substances; many of them solvents classified as Persistent Organic Pollutants (POPs)

Perchloroethylene, is widely used as a dry cleaning solvent and is a highly toxic chemical classified as endocrine disruptor and as neurotoxicant too.

Female employees, whose health was affected by to toxic chemicals, chose to run a "wet cleaning" shop.

Challenges:

Laundries in which cleaning processes are performed without hazardous substances can be an alternative for green entrepreneurship.

Process:

We change the cleaning process using percloroetilene.

Wet cleaning processes that use water, soap and water vapour offer similar results to those of dry cleaning, without any health and environmental risks.

The washing of garments in laundry shops is mostly carried out through "dry cleaning". This is a fast procedure that prevents garments from shrinking. Dry cleaning is carried out on the basis of perchloroethylene, a highly toxic solvent, hazardous to human health and to the environment.

In this case, female employees from a laundry shop that used perchloroethylene for more than twenty years, decided to set up their own laundry business using an alternative system. They opened a franchised laundry shop in 2008 (the parent company was Electrolux). The new company used a wet cleaning system as a substitute to dry cleaning. "Wet cleaning" uses washing machines based on water, water vapour and natural soap and has no toxic effects. Workers reported that in dry cleaning shops employees suffered headaches. Headaches disappeared with the new wet cleaning system.

Results:

The system is suitable for the cleaning of all type of garments with the same results.

[23] SUBSPORT is a EU substitution project http://www.subsport.eu/

The new system is less expensive for a number of reasons: it consumes less electricity, it eliminates the growing costs of perchlorothylene and the costs associated to the disposal of hazardous wastes.

A report filed by Greenpeace[24] estimates that wet cleaning systems require 41% less investments and provide 5% more benefits and increase qualified jobs by 21% compared to systems based on perchlorothylene.

Advantages:

- ✓ No human or environmental hazards
- ✓ Garments come out cleaner and softer
- ✓ Improved the odour of garments and the air quality in the laundry shop

This substitution fully eliminates occupational and environmental risks caused by the use of perchloroethylene and environmental damages caused by its wastes (For further information see: http://www.subsport.eu/case-stories/109-en?lang=es)

2 - Example of Construction using sustainable material[25]

Examples of this practice are found in the Substitution process of Polyvinyl Chloride (PVC) floorings.

A policy to avoid toxic materials was implemented in the construction of the Center for Research and Energetic Resources (CIRCE) in Zaragoza, Spain.

Situation:

Several toxic materials which represent significant risks to human health (both for construction workers and building users) are used in construction.

PVC floorings are an example of those materials that can even continue to release toxic substances after construction is completed. PVC floorings contain hazardous chemicals like vinyl chloride (carcinogen and neurotoxin) and phthalates (endocrine disrupting substances), as well as Di (2-ethylhexyl) phthalate, Di-"isononyl" phthalate, Benzyl butyl phthalate, Diethyl phthalate and Chloroethylene. In this case natural linoleum was used instead of common PVC flooring for the paving of offices and corridors.

Challenges:

Remove the use of these hazardous substances by replacing them other that do not cause harm to health and the environment.

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[24] Greeenpeace.Safer quemicals within reach https://www.google.es/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCQQFjAA&url=http%3A%2F%2Fwww.greenpeace.org%2Finternational%2FPageFiles%2F24502%2Fsafer-ch

[25] SUBSPORT. A EU substitution projetc. Available on: http://www.subsport.eu/case-stories/123-en?lang=en

Process:

Natural linoleum is a non-toxic, sturdy, water resistant material with bacteriostatic properties which make it suitable for use in hospitals.

Wood, stone and ceramics are also alternatives to PVC floorings, but natural linoleum was traditionally used before vinyl floorings appeared. Linoleum is a mixture of solidified linseed oil, cork powder, natural resin and several pigments.

Finally, a rational management of resources is regarded as an opportunity to seize for both for its job creating potential and for its environmental advantages. Market expectations extend to the manufacture of products using recycled elements.

2.3. Paxymer® (The business case)

The Paxymer® business case will be used to highlight the ways that one can formulate a vision, mission and business strategy of a start up.

History

PP Polymer was founded in 1985 by Dr Swaraj Paul to work with environmental and health conscious development of polymer problems. It quickly became a last resort for problem solving in the field of polymers in northern Europe. If issues were too tough or if the material suppliers were not able to find solutions, PP Polymer would be contacted to take on the project. Customers like ABB, GE Healthcare, Kodak, Micronic and many more were involved with troubleshooting projects, material development projects, advanced chemical analysis etc. One of the main principles of the company was that once an assignment was taken on, the undertaking included meeting functional requirements but also utilizing the best available technology from an environmental and health perspective.

In year 2000, the Swedish Civil Contingencies Agency approached PP Polymer after having studied apartment fires. They had concluded that polymer materials and especially flame retarded polymeric materials (i.e. plastics), created many issues in the burning scenario. Flashover times had gone from 15 minutes in the 1950s to a mere 2-3 minutes in the middle of the 1990s. Their definition of the flame retardant problem was wider than what material developers were considering at the time. Smoke amount and smoke toxicity, heat release rate and dripping (flame spread) were the most problematic aspects of how plastics/polymers behaved in the fire situation. The flame retardants on the market, further deteriorated these aspects rather than improve it. PP Polymers assignment was to investigate the potential to eliminate bromine and improve fire safety while avoiding hazardous chemicals. After delivering the report (available on Subsport) the company continued the work and filed for a patent in 2006.

When the technology was starting to take shape Paxymer® began the work with bringing the technology to the market. In this first phase,Paxymer® worked with lead users and their specific issues getting to know the technology. Another important part was creating partnerships with manufacturers so that Paxymer® was able to deliver samples for evaluation. Although the market was immature, there was an initial interest in the products.

Paxymer® applied for a government grant shortly after starting up in order to finance a production facility of its own. Partners seemed to have alternate agendas and kept delaying deliveries. Paxymer® invested in a small scale production unit in 2007 and further invested in a large scale production unit in 2009, following the government grant.

The legal entity Paxymer® AB was created in 2010 when the company broadened its marketing effort by targeting a wide range of companies all over Europe. Sales resources were enlisted and the company launched its products to lead users across Europe. Focusing on converters and compounders for thick walled plastics.

Paxymer® has since then gradually improved turnover and has grown the active customer base year on year. The company is currently involved in about 40 development projects with companies across Europe and has 6 buying customers. The technology has gained considerable interest across the world through continued participation in technical conferences (such as Antech (USA) and AMI Flame retardants in Plastics (Germany)). Some of the largest plastics and chemicals companies in the world are currently on the roster for development projects and the turnover is expected to multiply over the coming years.

Paxymer® AB is and has been financed by the group owned by the family. The value proposition of the product is functional, environmental and safety improvements of the material compared to conventional flame retardant systems.

Mission

Paxymer® protects people and environment and is the number one green flame retardant system for polyolefin plastics.

Vision

Paxymer® is a leading centre of excellence for all its stakeholders within our field of operations.

Key company milestones:

- Filed for patent 2006
- First customer trials 2007
- Reformulation of new product 2007/08
- Investing in manufacturing capability – small scale -07. Full scale -09.
- Creating limited company and setting up sales structure 2009/10
- Recruitment of professional board 2010
- First regular customer 2011
- Launch of new generation of products 2012

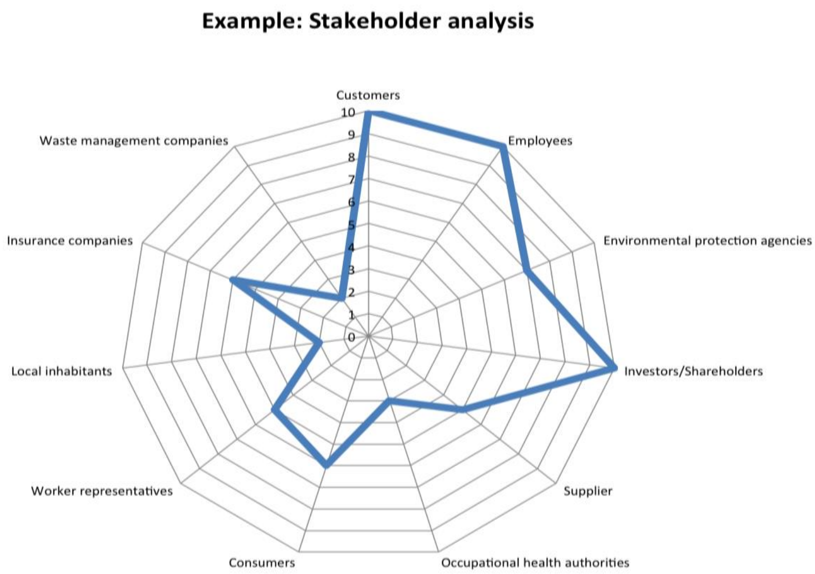
- Project financing for FR solution for fibres 2013.

Stakeholder analysis

When making a stakeholder analysis it is important to first apply a brainstorming perspective to find all stakeholders. Second step is to list targets, activities, risks and opportunities connected with each stakeholder and finally, one should cross-reference the stake holder analysis with the company short and long term goals. This will provide a base for prioritizing tasks.

There are many stakeholders in any company, it is impossible to fully cater to all of their needs therefore it is important to determine the stakeholder potential impact on the market development of the firm with different time perspectives. Closer in time for the impact and higher gains would indicate a high priority as far as internal resources and vice versa.Utilizing the list from figure 2 under 4.1.4 above, we have made a polarity diagram of the expected impacts of different stakeholders in the Paxymer® case.

Figure 5: Stakeholders analysis' impact



Starting with customers, the aspects are rated clockwise from strategic importance. Underlying each of these numbers is a thorough analysis but this is a good way of creating an overview of the entire playing field and thereafter prioritizing resources depending on the business strategy. It is also possible include a second line in the polarity diagram that would represent the priority given and resources spent to each stakeholder.

Reading the diagram for Paxymer® , one can conclude that customers and employees are main resources in achieving its goals. Environmental protection agencies are also important since they set the playing field for hazardous chemicals. Investors and shareholders, have to believe in the firm, suppliers are important to have good relationships with but since raw materials are interchangeable they have limited power. Occupational health agencies have historically not been focused on issues that concern us but are gradually increasing their awareness and influence over these issues, therefore they get a low score on the potential impact but are on upper half of the list of Paxymer® 's prioritized stakeholders and so on.

Barriers and opportunities for innovation

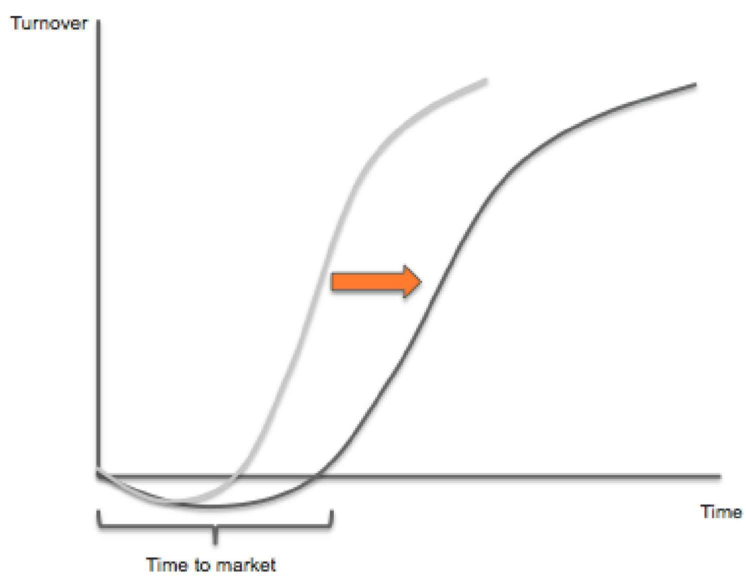
There are several barriers to innovation that have to be overcome by an aspiring venture. We will address some of the more common ones in the coming segment and also give some insight in how to mitigate their effects on a venture. The proposed solutions are often generalizable but we have applied the case to give some real experience on how to work with these issues.

The biggest challenges for the Paxymer® venture:

- Timing/Market maturity

Timing is crucial when starting a venture. It depends virtually on the market maturity. Market maturity in turn is a function of what legislation is in place, customer understanding of the issue, urgency of customer pain etc. A venture that is too early on the curve of its life cycle, will have a long time to market and a long time before entering into the growth phase. A venture that is too late might, on the other hand, miss the so-called first mover advantage and will have to resort to price competition to gain market share. Entering a saturated market will also hamper the possibility of rapid expansion.

Figure 6: Venture life cycle: Market maturity will shift the time to market into the future, this can provide a significant financing challenge for new ventures.



Paxymer® case: Paxymer® was ahead of its curve and therefore one of the key aspects has been cost control and creating longevity for the innovation in order to capture the market shift. Mitigating the disadvantage has had a large imprint on Paxymer® 's marketing strategy. Firstly, finding and building relationships with lead users have been critical. Helping direct customers to approach their customers and including a bigger part of the supply chain, or what is popularly refereed to as "backdoor selling". Involving the OEMs/brand owners and consultants as well as subcontractors in order to get the issue up on the agenda.

Secondly, focusing on markets where these questions are already regarded a priority. The main market has been Northern Europe and northern Central Europe for Paxymer® since they have been more focused on hazardous materials and sustainability. Conventional wisdom says: start close to home – in this globalized world it is more important to start where you have the best preconditions for success.

- Understanding of value proposition

Tech companies are often driven by a technical innovation, an invention at the heart of the business idea and an ideal view that the best product will automatically win the contract. In reality this rarely happens. There are a number of factors that will have impact on the success or failure of a new technology and these relate to the management team's understanding of a products value proposition. We ended the last paragraph by stating that a venture should focus where they have the best preconditions for success – it is important to define these preconditions in wider terms than just technological proficiency of a product. The entrepreneur has to be well connected to the purchasing process, the production process, the budget process, the power structure, the problem formulation etc. of the customer. With this wider definition of preconditions, geographical and cultural distance should also impact the decision on which market to target first.Paxymer® started up In the classical scientist trap – thinking that superior performance would gain us enough market advantage. The initial value proposition was formulated from the investigation we had made with the Swedish Civil Contingencies Agency – improved fire safety. However, the industry cares about fulfilling specified burning standards and coercive environmental legislation not improving fire safety or saving the planet.

Paxymer® case: The first customers were acquired due to good mechanical and processing properties of the product as the main argument and environment and fire safety the the company was pushing as their main selling point as added benefits.

Recently, sustainability aspects are becoming increasingly important but that is due to an evolving legislative landscape with new standards and regulations that companies have to comply with. The best way to achieve understanding of any product's value proposition is close and frequent contact with potential customers.

The value proposition will of course also differ beteween different customers. Paxymer® now maps the product benefits as well as customers network and processes at a first meeting, paying attention to everything from purchasing process, to relevant market demands, to their supply chain structure and dynamic.

Finally it is important to realise that a product will never be "finished" in a tech company. Paxymer® contacts customers and offers what is currently available, and while doing that gets inspiration for new developments and products. The idea is to sell what you have and while doing that form relationships that will give you a shorter start up process when the product has been further developed in the future.-

Market structure/Conservative market

All markets are conservative. It makes sense: if you have an on-going business you want to avoid new investments unless they are necessary since new investments reduce profits in the short term. Take this into account, when making your marketing plans there are a few learnings that are worth considering when formulating your marketing strategy:

- ✓ Find the right partner for innovation. Subcontractors do not innovate – as a rule. Subcontractors fulfil OEMs (Original equipment manufacturers) requirements, if you need to change the rules of the game you need to form technical alliances and/or approach brand owners.
- ✓ Understanding the market structure is just as important as understanding the technology. This helps you formulate and focus on your value proposition.
- ✓ Developing customer relationships are equally important to developing a superior product. And takes time and resources. Finally remember: purchasers are people too – they also have passions and interests (apart from price).

Brand owners can be a good way to gain access into subcontractors. Paxymer® has had a long relationship with a local truck manufacturer and due to the good contacts they kept introducing the company to their subcontractors and consultants in turn. The truck manufacturer has benefit from the full value proposition and understands strategic and marketing potential of the Paxymer® innovation – it makes sense for them to spend resources to develop a new alternative. However, from a subcontractor view, evaluating Paxymer® is percieved as more work with very little benefit, therefore they are more reluctant to drive innovation.

- Education of customers

Education of customers is another symptom of timing. The earlier in the cycle you are, the less your customers and stakeholders will understand the benefit of your product. However, it is efficient to make sure that your stakeholders understand your definition and solution to the problem even though the current interest may be low, corporate policy, regulation and standards change.

In fact, fire safety definitions, legislation, REACH, EU-legislation, tools for substitution have all been developed during the last five years. Education of customers is not a quick fix, reachable over night but it is an important part in positioning and relationship building that will eventually enable them to act quickly when the timing is right for their organisation.

An example from Paxymer® 's experience is a multinational company in the white goods industry. Initially the company showed interest but when we started to discuss concrete actions, the line went more or less dead and company representatives were unavailable. Almost 2.5 years later, the tone changed completely, high interest from the same people that had long since been stalling and access to both strategic purchasing and the technology team.

Another example of customer education is information and participation in the public debate. Paxymer® is a small entity but is involved in a number of activities and conferences in order to stay informed on the latest trends within the field of hazardous chemicals in all industries. Constantly communicating with customers directly through newsletters (5-6 per year) and addressing the industry during conferences speaking on the topic of flame retardants in general are direct activities. Cultivating relationships with important lobby groups and organisations and participating in and submitting comments to on-going legislative investigations in the EU and Stockholm conventions are examples of activities that indirectly educate customers.

- Financing

Generally speaking, when financing and entrepreneurship are mentioned in the same sentence, people think about venture capital. This is a very narrow definition of financing and it doesn'tnormally suit industrial innovations in their early stages because of mismatch between the time to market and investment horizon. For Cleantech ventures, that should be (as stated above) compared to industrial entrepreneurship rather than the Internet boom, other sources of financing in the early stage is necessary. Here are a list of a few sources to consider:

- ✓ Government investment programmes are normally available either directly from the country, EU or other associations. There is a wide range of initiatives available but they vary depending on location.
- ✓ Customer funding is probably the best type of funding – this creates an alignment between organisations. The customer will cover some cost provided that they can reap the benefit.
- ✓ Corporate venture capital that will also connect the venture to their development or market department. Corporate venture capital is normally available with big firms which are scanning the market for relevant technologies in their own field of business.
- ✓ Venture capital – there are new breed of venture capitalists that are focused on green ventures with longer investment horizons however these normally step in at when the firm has survived the development phase. In Sweden that is considered to take place when the company has a turnover of 3-10 million €.

Financing is a challenge for growth. However, it is also important to find financing with patience – a short investment horizon, can be a threat to a venture in the developing Cleantech sector since market maturity and time to market are so hard to predict. A VC investor that gave a presentation during Stockholm Entrepreneurship Day 2012 said that the average investment horizon of a VC-fund is five years, however in reality the average timespan from pitch to exit is 12 years today – in the ICT sector.

Paxymer® 's financing model is unconventional – it is financed by an on-going consultancy business. All the surplus, goes back into the organisation to finance the growth. Benefits of such an arrangement, is the endurance that we gain and also the alternative door opener into customers through a brand they already know and trust. The downside has been a partial lack of focus at times since there are many projects on going simultaneously.

3. Identification of chemicals of high concern

3.1 Criteria and definitions for substances of high concern

Around 104,000 substances circulate in the European market of which 30,000 are considered of daily use at workplaces.

Choosing priority substances for elimination or substitution implies defining criteria to classify them as "substances of very high concern".

Chemicals are dangerous for a number of reasons (they can be flammable, explosive, corrosive, comburent, irritant, harmful, toxic or hazardous to the environment).

Toxic substances may cause serious effects to human health. Those effects can be acute (if they occur immediately after exposure) or chronic (if they occur within days or even years of exposure).

Acute effects include burning, irritation of the eyes, skin or airways, asphyxia, dizziness, etc. experienced within seconds or even a few some minutes of exposure.

Chronic effects include allergies, asthma, cancer, respiratory conditions, reproductive and hormonal disorders, etc. Such effects may appear within days, months of even years of exposure and usually occur after continued low-dose exposure to toxic substances.

Environmental hazards include toxicity for living organisms, capability to pollute the water, the air or the soil, persistence and bioaccumulation.

Different individual response, as well as, gender factors or specific sensitivity to toxic substances must be taken into account.

Finally, we must also considered the great amount of products to which we are exposed in our daily lives and the multiple sources of exposure: occupational, environmental, nutritional, etc., which make multiple exposure to different substances with long-term health effects the most common way of chemical exposure.

A substance's intrinsic risk is the most reliable information that can be used to list substances of high concern. Substances of the highest concern include those that in a long-term cause irreversible health and environmental effects.

Control on health and environmental damage is based on the precept that damage caused by a substance depends on exposure and on intrinsic toxicity, to such extent that implementing control measures may prevent or at least reduce occupational diseases and environmental damage. There are however groups of substances for which such precept is not valid due to their intrinsic properties. They may bio-accumulate, be persistent or cause damage at very low or even at any level of exposure. Those substances include:

- ✓ Carcinogenic: is a substance that may cause cancer or increase its incidence by inhalation, ingestion or skin absorption.

- ✓ Mutagenic: are substances and mixtures which, if inhaled, swallowed or absorbed through the skin, may induce heritable genetic damage or increase its incidence.

- ✓ **Toxic, persistent and bioaccumulative (PBT), very persistent and very bioaccumulative (vPvB):** are substances of very high concern because of their persistence, their ability to accumulate in living organisms, their capacity of travelling long distances and mainly their high toxicity.

- ✓ Toxic to reproduction: A reproductive toxicant or reprotoxicant will impair the ability to get children or cause irreversible harm to the offspring itself. Alterations include miscarriages, damage to unborn children's development, alteration of breastfeeding capability, or negative inherited developmental effects.

- ✓ Endocrine Disruptors: is a chemical that can interfere with animal and human endocrine (or hormone) system causing several adverse effects on exposed individuals and/or their offspring. Adverse affects include cancer, behaviour alterations or reproductive disorders among others.

- ✓ Sensitizers: is a substance with the potential to act, through whatever mechanism, to create a situation of airway hypersensitivity.

- ✓ Neurotoxicants: are substances capable of causing adverse effects in the central and peripheral nervous system, and in sense organs.

- ✓ Those that may cause long term adverse effects in the aquatic environment: are substances that represent a substantial damage to living organisms and human health through aquatic exposure. Effects include among others, damage to the reproductive, immune, endocrine and/or nervous systems, cancer and even death.

Once the most concerning properties of a substance are determined, the person or organization willing to eliminate or substitute the hazardous chemical must establish a priority for substitution.

Several lists of extremely hazardous chemicals developed by government agencies or nongovernmental organizations with different purposes do exist, with the common denominator of containing those substances that are considered of special concern because of their negative effects on human health or environment. It is very useful to know these lists in order to identify chemicals of high concern in a practical way.

An overview of the criteria and lists that we can use to identify substances of concern are listed in Annex I.

3.2 Identification of hazardous conditions

Once the problems, hazardous substances and hazards have been identified, it becomes necessary to define the type of risk that stems from each situation.

At this point and before taking any further action it becomes necessary to agree upon terms and define hazards and risks.

Hazard: is a property or characteristic of a substance which might cause damage to human health or the environment.

Risk: is the probability that such substance might eventually cause damages in certain uses or conditions.

In order to determine the potential **hazards** of a substance its only required to know its physical and chemical characteristics, as well as their toxicological (human) and eco-toxicological (environmental effects), but to determine the risks that the use of a substance implies, we must know exactly which circumstances and conditions of use make that risk possible, i.e.: **risk factors.** For example, sodium hydroxide (caustic soda), a highly corrosive substance, represents very little risk if it is used diluted in water. A non-ionic surfactant that may alter the hormone system, contained in detergents and cleaning products, may represent a negligible risk for human health but it may cause serious damage to the environment if dumped into waste water.

Besides, the use of some hazardous substances will always be undesirable, regardless of the conditions of use, since their very existence at the workplace or in the work environment implies serious risks. That is the case for carcinogens, endocrine disruptors, persistent and bio-accumulative substances. **Their elimination must always be a priority**.

Hence, detecting the risks means understanding the relation between their hazardous properties and the conditions of use, handling and disposal which determine the resulting exposure for workers and for the environment. Factors with most influence on chemical risks

- ✓ Existence of **specific personal conditions:** age, infancy, pregnancy and lactation, particular sensitivity or poor health
- ✓ Lack of information on used products
- ✓ Work organization and work intensity: general experience shows that these are the conditions with most influence on chemical risks. They cause multiple accidents and unnecessary exposures
- ✓ Existence of effective occupational/environmental control measures or lack there of them

The following table shows some major **risk factors** which determine occupational and environmental risks of using chemical products and substances.

Risk	**Risk factor**
Fire or explosion risks	High atmospheric concentration of flammable substances. Presence of ignition sources. Simultaneous presence of incompatible substances.
Chemical reactions risk	Manual mixing of substances. Uncontrolled presence of subproducts. Lack of proper work procedures in dangerous operations (sampling, charging additives).
Inhalation risks	Presence at work environment. Daily time of exposure.

	Insufficient ventilation systems. Inadequate work procedures. Particularly sensitive people.
Absortion through skin	Duration and frequency of contact. Simultaneous contact with various substances. Particularly sensitive people. Agent concentration. Inadequate PPE (Personal Protective Equipment)
Swallow risks	Inadequate personal hygiene habits like eating or smoking in the workplace.
Chemical agent contact with eyes or skin risks	Inadequate work procedures. Inadequate container. Inadequate PPE (Personal Protective Equipment)
Enviromnental risks	Product or waste packaging: open, broken, mislabeled or not properly segregated. Risks from chemical plants failures. Leaks, spills or discharges. Substances or products discharges into waterways (drainage, rivers, sea, land). Uncontrolled waste. Emissions to air through chimneys, ventilation systems or fugitive. Waste deposit in soil, seepage or spills.
Women health risks	Exposure in reproductive-aged women Exposure in pregnant and lactating women. Double Exposure: at work and at home.

3.3 Focusing on the usual suspects: the "six-classes" concept

The **"Six-classes",** a concept developed by the Green Science Policy Institute of California[26], aims to simplify the process of classifying the many thousands of harmful chemicals in consumer products and facilitate the selection of alternatives to avoid regrettable substitutions, and is presented in the form of webinars.

[26] The Institute seeks to provide unbiased scientific data to government, industry and non-governmental organizations to facilitate informed decision-making about the use of chemicals in consumer products, and to encourage scientists to use their research in the public interest

The “**Six-classes**” focuses on six chemical classes that contain a large proportion of the known harmful chemicals that are used in many consumer products but are not yet adequately regulated. In addition, the series move towards solutions by asking, “Do we need these chemicals?” and when the answer is “Yes,” safer green chemistry alternatives are explored.

All the information is accessible in the format of webinars at the website www.sixclasses.org/. Each 30 minute webinar consist of a 5 minute introduction and a 15 minute lecture from distinguished scientists, followed by a question and answer session

Chemicals used in foods, drugs and pesticides are not included because there are laws that regulate these to some extent. The six classes containing chemicals of concern are:

1. **Per- and Polyfluoroalkyl Substances** (stain and water repellants) : Fluorinated chemicals are used in cookware, clothing, outdoor apparel, carpeting, and food packaging to provide oil- and water resistant properties. They are persistent in the environment and have been detected in humans and biota all over the globe. In humans, some fluorinated chemicals have been associated with kidney and testicular cancer, thyroid disruption, elevated total cholesterol, and obesity.

2. **Chlorinated anti-microbials**: Anti-microbials, such as triclosan and triclocarban, are used in products from soap, deodorant, and toothpaste to socks, lunchboxes, and counter tops to prevent microbial growth. Antimicrobials can be ingested or absorbed through the skin. They are a concern because they are associated with adverse endocrine, thyroid, and reproductive changes and their use can lead to resistant strains of bacteria. Soap and water can be a better alternative

3. **Flame Retardants (brominated, chlorinated, and phosphate):** Flame retardants are used in furniture and baby product foam, building insulation, electronics, and other products to reduce fire hazard. The highest levels are detected normally in children, and they have been associated with endocrine disruption and reproductive, neurologic, and immune impairment as well as cancer. As currently used in furniture, building insulation and some other products, flame retardants do not increase fire safety.

4. **Plasticizers and other Endocrine Disruptors** : Endocrine disruptors (BPA, phthalates, etc.) interfere with the hormone signaling mechanisms of the human body. They are found in plastics, pesticides, flame retardants, and other products and are measured in all humans. EDCs cause disruption to reproductive, metabolic, neurologic, and immune systems and the thyroid at very low concentrations and are most harmful during critical windows of development of the fetus.

5. **Solvents** : Solvents (methylene chloride benzene, toluene, etc.) are used in paint, coatings, degreasers, dry cleaning chemicals, and many other products in order to dissolve other chemical constituents. Many non-water based organic solvents release vapors that humans inhale and absorb. Some solvents are associated with neurotoxicity, reproductive toxicity, and carcinogenic effects during short-term high level exposure and over prolonged periods of low level exposure.

6. **Heavy Metals:** Heavy metals, like lead, cadmium, and mercury, have been harming human health for millennia. Heavy metal toxicity can result in reduced mental and

central nervous function, lower energy levels, and damage to blood, lungs, kidneys, liver, and other organs. Some heavy metals like zinc that provide a health benefit in small doses can be toxic at high levels.

The first three groupings of chemicals above are all organohalogens (compounds in which carbon is bonded to bromine, chlorine, or fluorine). These chemicals are often toxic, lipophilic (fat-loving), and/or resistant to degradation, leading to their persistence and bioaccumulation in our bodies and the environment. All 22 chemicals globally banned as Persistent Organic Pollutants under the Stockholm Convention are organohalogens. Other organohalogens in these three classes are still used at high levels in consumer products, in spite of their similarity to chemicals that have been banned or phased out.

The fourth class comprises the commonly used endocrine disruptors phthalates and BPA, which are ubiquitous in plastic products and our bodies. While nearly all the listed chemicals in the six classes are suspected of having endocrine disrupting qualities, these plasticizers deserve to be targeted due to their high volume of use and adverse impact on biological systems at low levels.

The final two classes are some heavy metals such as lead, arsenic, mercury, cadmium, and chromium and certain solvents such as methylene chloride, benzene, and toluene. Exposure to these many heavy metals and solvents has, in numerous research studies, been associated with reduced IQ, cancer, and neurological or reproductive impairments.

All the webinars, slides and fact sheets are on public display at the website www.sixclasses.org.

4. How and where to identify alternatives?

4.1 Use, function and need of chemicals

In order to identify alternatives to a specific hazardous substance it is necessary to understand why this substance is being used and to know the specific function of the chemical in the **process** or in the **product**. For example, is it intended to dissolve materials (i.e. solvent), to preserve the product from microbiological degradation (i.e. biocide), to provide a scent (i.e. fragrance) etc...? We will also need to know the specific requirements for that use, like temperature, pH and influence of other reagents that are part of the application.

It is important to have a wider view and understand what the chemical was used for. If we have a broad view of the role of the substance we may find not only alternative substances, but also alternative processes or even organisational changes that might avoid the need to use chemicals at all.

For example, the use of a degreaser satisfies the need to keep a surface clean from grease or oil. Perhaps we may find an organisational change that favours cleaner surfaces and therefore avoids degreasing. Quality norms may also be checked as many times the use of hazardous chemicals may be avoided if a lower quality is sufficient, for example when cleaning or painting.

Function refers to the intrinsic property of the substance that is technologically important to the specified **use** and to satisfy the specified **need**.

Use refers to the application of the function in a process/product.

Need refers to the ultimate benefit for the user. Needs may be reflected by norms (e.g. quality or safety norms) or may be inspired by customer/users' preferences or by the efforts to overcome competition. Needs, as defined here, may be stringent and compulsory (fire safety) or optional (bright finishing, fragrance).

These aspects may influence how we identify alternatives, as well as the type of alternative and the relation with the stakeholders that are most concerned/affected by the change.

4.2 Tools and sources of information to identify alternatives

Several sources of information may help us to find alternatives:

Inside company knowledge: our own company may have the knowledge to find alternatives once we have identified the function of the hazardous substance in our product or process. Several departments may provide information: environmental, health and safety, quality or purchases.

Workers: who carry out the tasks with chemical agents and know well their function may have proposals for alternatives.

Suppliers: in many cases usual suppliers can provide a less hazardous product. In particular if they understand that they may lose a client.

Databases: several databases compile cases stories and technical information on alternatives. The SUBSPORT Case Story Database provides a compilation of such examples/information. A search engine to access other databases can also be found on SUBSPORT. (http://www.subsport.eu/case-stories-database)

Industry publications and websites: provide information about what is currently being used in the market and may help identify companies that are using alternatives. Some company sites offer to collaborate for tailored solutions.

Scientific literature: may provide information on chemicals that are being researched for the specific use or for similar uses that meet the same or similar requirements.

Technological institutes, clean production centres.

Associations of interested partners: e.g. The Swedish National Substitution Group for Hospitals and Universities, EPA partnerships, etc.

Occupational, health and safety (OSH) consultants

Trade Unions and environmental NGOs: working on pollution prevention or chemical risks publish materials on alternatives.

Internet search: in some cases a direct internet search may provide information on possible substitutes. Green chemistry websites, green chemistry awards (e.g. EPA), lists of certificated “responsible” products (e.g. FSC), plant based chemicals etc.

Substitution related websites and database are listed in Annex II, where alternatives can be found.

4.3 Green product development: inspiring approaches

The idea of green product development is supported by research to yield better financial returns. Recently 90 companies across a number of industries with active sustainability policy and where sustainable/green product development was the main driver behind innovation were compared with 90 companies that do not work with these tools. The conclusion is remarkable – companies that have sustainability ambitions perform on average 4.8% better when comparing return on equity and return on assets.

What guidelines should one use in order to achieve these results? What can be defined as sustainable innovation?

Starting with green innovation it’s important to understand one of the basic principles of environment legislation: the precautionary principle. It is a long-standing principle in European environmental legislation – it means that the burden of evidence falls upon the supplier of a hazardous substance where there is scientific uncertainty. The supplier has to prove that a compound is not hazardous.

The precautionary principle is gradually working its way into most of the environmental legislation shifting responsibility for products onto the producers. The definition of producer in the EU-terminology is whoever puts the product on the EU-market – including agents and distributors. The idea is to force companies to take their responsibility and ensure the safety of their products. It does however increase cost of new product development which especially strikes against small firms and start-ups.

The precautionary principle is often used by environmentalists and researchers as an argument for questioning new product development. It is not uncommon that new product development in response to legislation fall into the category of incremental/regrettable substitution. This means that a supplier changes the compound minimally with the sole purpose of circumventing the ban. Full implementation of the precautionary principle would make this type of innovation impossible.

In contrast to "regrettable" substitution, green product development focus on a products primary functionality. Weighing functionality against the hazard profile of the substances used and finds a way to keep the functionality and reducing the hazard profile. Prioritization in product design is a crucial concept in green product development – focusing on need to have properties rather than nice to have properties is essential to provide cost efficient, functional solutions with better hazardous profile.

Example: When Paxymer® started developing its flame retardant solution, the dominating type of flame retardants on the market was brominated. The performance criteria for flame retardants were self-extinguishing properties where halogens (bromine included) are very efficient. Paxymer®'s approach was to aim to achieve fire safety in the wider sense, controlling flame spread, decreasing smoke and dripping that contribute to rapid fire scenarios – by redefining the issue new possibilities were found. The approach was unconventional when Paxymer® started marketing its solutions but with implementation of new standards the bet on functionality paid off and demand increased over time.

Inspiration for green product development can be found in voluntary goods declaration initiatives, two examples are Building Goods Declaration in Sweden and POPs free projects run by UNEP. These organisations have criteria set up for product evaluation, by going through them one can find much information about what the lead users in an industry are considering "need to have properties" in new product development. They rate products based on submitted information or analysis from suppliers according to set criteria; chemical content, transportation, manufacturing emissions etc... are all included in the evaluation. This is a good way to differentiate green products and deliver value to the end customers.

Example: Paxymer® is active on the pipe and conduit market – specific standards define them as halogen free if they contain <1500 ppm of halogen content according to a specified testing method. In practice this means that most products on the market are flame retarded by using halogens but the products are sold as "halogen-free". Customers were perplexed when they were told that they should substitute a halogen-free product with another halogen-free product. When Paxymer® was certified for the Swedish Building Goods Declaration and got a "Recommended" status this showed manufacturers it was really a one of a kind system, which opened doors into new customers, increased customer value and motivated a difference in price.

Example: Paxymer® was part of a project called "POPs-Free Products" project initiated by UNEP – this came at a cost of almost 3500€ for a thorough analysis of the Paxymer® products. The concept was that submitted compounds were tested against a list of hazardous chemicals by an independent third party. The benefit of this approach is that instead of having to disclose confidential information or know-how Paxymer® could communicate with potential customers providing proof that it fulfils the strictest of standards when it comes to hazardous chemicals.

Another source for inspiration and benchmarking when working with green product development are NGOs such as Greenpeace and Chemsec[27]. They present recommendations and restrictions both from the legislative side and from the research front - staying up to date with their communication will give an idea of what the current and coming trends and opportunities are within green product development. A tool for verifying any new innovation that is safe from a legislative point of view is the SIN-list published by Chemsec.

Example: Greenpeace makes lists where they rate companies' use of hazardous chemicals. They started with the electronics industry and have now moved on with the same concept to the textile/clothing industry. By initially shaming big, well-established brands, Greenpeace invokes change and gets commitments from the major companies to alter their behaviour.

Once companies commit to taking action against a certain chemical or product Greenpeace will assist in the process and also provide a marketing platform for the companies that are driving the change.

4.4 Innovation in practice - balancing "green" and function in different markets

When approaching the topic of green entrepreneurship a common misconception is that "green" alone will sell the product. As discussed above, it is important to thoroughly understand your market and its processes in any sales scenario.

Mapping all benefits of your product and making a full cost benefit calculation of the product is important to create demand for any new product. The framing on unique selling points will depend on who your end customer is and what markets they are active on.

Consumer markets vs. Industrial markets

Products directed towards consumers are increasingly using environmental arguments as their primary marketing argument, from vacuum cleaners with recycled material to increased use of biodegradable materials.

The eco-ambition of some of these earlier products can be questioned – standards for bio-materials have been exploited and loop holes used in order to package products as green materials. Times are however changing and brand owners are getting increasingly efficient at catching so called green-washing initiatives.

[27] http://www.chemsec.org/

The marketing power of green products is increasing on consumer markets. Many of the multinational companies are working hard to integrate corporate social responsibility and sustainability parameters into their business strategy, including circular economy arguments and cradle-to-cradle concepts[28].

It is important to know what the definition and focus of the sustainability is in your industry – is it energy, carbon footprint or zero discharge? What are the brand owners' responsibilities? What do the market leaders do and what do the rest of the actors do? How does your product offering fit into this concept?

Looking at the structure of industrial markets that do not directly connect with consumer applications – the jargon is different. The reasoning is mainly functional and economical; not meeting the cost benefit will make any sale much more difficult. Apart from the cost-benefit parameter, the sales process must fit into the customer's buying pattern, and to enable rapid implementation, the product should be packaged in a way that the customer is used to handling. That means that they will not have to make extensive new investments in order to implement the technology.

Industrial markets also differ in the aspect that they are more immune to public pressure. The "Greenpeace-model" (described above under 4.4.3) of shaming companies into more sustainable behaviour is much more efficient in the case of H&M than in the case of Shell. Where consumer markets are more sensitive to this type of activism, industrial markets spend significant amounts on lobbying and counter campaigns to any change initiative they can find. They are also however every now and then forced to recognise defeat. A famous example is the case of the "Citizens for fire safety" which was launched as a public interest group in 2007 and later was exposed as being completely funded by Albermarle, Chemtura and ICL – three of the biggest manufacturers of brominated flame retardants with a 40% worldwide market share. The group advocated for specific standards and countered research with their own studies showing doubtful benefits and little to no concerns regarding their products. The group was exposed in 2012 and closed down later that year.

Green vs. functionality?

The second topic in this segment is the question of how far the green argument will take you.

The answer is unfortunately not that simple since it depends on several parameters. For instance:

- ✓ In the consumer goods scenario an innovation that solves a problem with similar functionality but with a better environmental footprint will be able to warrant for a small price premium as a rule – in the industrial case this is normally not the case.
- ✓ Larger investments and longer development projects for full implementation and integration of new solutions are on the other hand more likely in the industrial scenario where volumes are typically larger. Whatever these positive "lock-in"

[28] http://ec.europa.eu/environment/circular-economy/;

http://www.c2ccertified.org/

effects of customers are they will also make the sales process longer and more complicated.

- ✓ In any case the customer will primarily buy in a cost-benefit. Finding a way to formulate your green benefits in combination with worker and user safety benefits and other benefits in economical terms is the most efficient

Therefore the understanding of the customers' process and priorities are the key success factors in any sales process.

Green will only sell on its own when it is related to pending coercive legislation in any other case green parameters will be weighed into the full cost benefit analysis but the customer will act on the most efficient overall alternative rather than the one with the best green performance.

What green will do on the other hand is ensure that any company is able to capitalize on the innovation and capture sustainable, long-term benefits from the innovation.

5. POPs' substitution and safe work procedures

5.1. What are Persistent Organic Pollutants?

Persistent Organic Pollutants (POPs) are organic chemical substances, that is, they are carbon-based. They possess a particular combination of physical and chemical properties. Once released into the environment these compounds:

- ✓ remain intact for exceptionally long periods of time (usually for many years): Persistence criteria established by the Stockholm Convention[29] are based upon their persistence in water, soils, sediment or air for a period of time

- ✓ become widely distributed throughout the environment as a result of natural processes involving soil, water and, most notably, air

- ✓ accumulate in the fatty tissue of living organisms including humans, and are found at higher concentrations and higher levels in the food chain[30]

Due especially to human activity, POPs are now widely distributed over large regions and, in some cases, they are found all around the globe. This general contamination of environmental elements and living organisms includes multiple foodstuffs and has resulted in the sustained exposure of many species, including humans, for periods of time that span over generations, resulting in both acute and chronic toxic effects. In addition, POPs concentrate in living organisms through another process called bioaccumulation.

Human exposure to certain POPs is associated with several types of cancer and tumours, neurobehavioral disorders, including learning disabilities as impaired reading, poor test performance, behavioural changes, and immune system disorders. Effects also extend to reproductive and sexual disorders, reduced breastfeeding periods in mothers, diabetes and other conditions. Women, newborn and children are particularly vulnerable to certain effects of POPs and many effects pass to the next generation.

Twelve POPs have been recognized as causing adverse effects on humans and the ecosystem and these can be placed in 3 categories:

1) Pesticides: aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene

2) Industrial chemicals: hexachlorobenzene, polychlorinated biphenyls (PCBs)

3) By-products: hexachlorobenzene; polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF), and PCBs.

At its fourth meeting held from 4 to 8 May 2009, the Conference of the Parties adopted amendments to Annexes A, B and C to the Stockholm Convention to list nine new persistent organic pollutants (SC-4/10-SC-4/18). Pursuant to paragraph 4 of Article 21 of the Convention, the amendments were communicated by the depositary to all Parties on 26 August 2009.

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[29] Stockholm convention website http://chm.pops.int/TheConvention/ThePOPs/tabid/673/Default.aspx

[30] http://www.ipen.org/toxic-priorities/industrial-chemicals

1) Pesticides: chlordecone, alpha hexachlorocyclohexane, beta[1] hexachlorocyclohexane, lindane, pentachlorobenzene;

2) Industrial chemical: hexabromobiphenyl, hexabromodiphenyl ether and heptabromodiphenyl ether, pentachlorobenzene, perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride, tetrabromodiphenyl ether and pentabromodiphenyl ether; and

3) By-products: alpha hexachlorocyclohexane, beta hexachlorocyclohexane and pentachlorobenzene.

According to the Stockholm Convention, parties have the following obligations:

Annex A - Parties must take measures to **eliminate** the use of:

Aldrin ●	Chlordane ●	Chlordecone ●
Dieldrin ●	Endrin ●	Heptachlor ●
Hexabromobiphenyl ▲	Hexabromodiphenyl ether and heptabromodiphenyl ether ▲	Hexachlorobenzene (HCB) ● ▲
Alpha hexachlorocyclohexane ●	Beta hexachlorocyclohexane ●	Lindane ●
Mirex ●	Pentachlorobenzene ● ▲	Polychlorinated biphenyls (PCB) ▲
Technical endosulfan and its related isomers ●	Tetrabromodiphenyl ether and pentabromodiphenyl ether ▲	Toxaphene ●

● Pesticide ▲ Industrial chemical

Annex B - Parties must take measures to **restrict** the use of:

DDT ●	Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride ▲

Annex C - Parties must take measures to **reduce the unintentional releases** of this chemical with the goal of continuing minimization and, were feasible, ultimate elimination

Polychlorinated dibenzo-p-dioxins (PCDD)	Polychlorinated dibenzofurans (PCDF)	Hexachlorobenzene (HCB)
Pentachlorobenzene	Polychlorinated biphenyls (PCB)	
Pesticide	Industrial chemical	

Source: Stockholm convention website[31]

5.2 Regulation on POPs

- ✓ Stockholm Convention whose goal is to limit POP contamination defines the affected chemicals, as well as rules for their manufacture and marketing

- ✓ Regulation (EC) N° 850/2004 on persistent organic pollutants is the legal framework for the implementation of Stockholm Convention in the EU. Adopted in Aarhus in 1998, as part of the Geneva Convention on Long-Range Transboundary Air Pollution (GCLRTAP)

- ✓ Barcelona Convention, adopted in 1976. This Convention and its six protocols were amended in 1995 to extend the geographical scope and include sustainable development principles of the Earth Summit in Rio (1992). The creation in 1996 of the Mediterranean Commission on Sustainable Development (MCSD) by the Contracting Parties *conveys their commitment to sustainable development and to the effective implementation, at the regional and national levels, of the decisions of the Earth Summit and the United Nations Commission for Sustainable Development.*

Related international regulation

- ✓ Regulation 1907/2006/EC (REACH). REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals. It entered into force on 1st June 2007. It streamlines and improves the former legislative framework on chemicals of the European Union. Under REACH regulation, existing and mew substances are subject to evaluation, authorization and restriction. The authorization process expressly addresses the use of substances of high level of concern, as may be the case with POPs.

[31] Stockholm Convention website http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

- ✓ Regulation (EC) nº 1272/2008 on classification, labelling and packaging of substances and mixtures
- ✓ C170 - Chemicals Convention, 1990 (No. 170)Convention concerning Safety in the use of Chemicals at Work

5.3 Safe work procedures

As indicated in paragraph 4.1, substitution is the priority to address hazardous chemicals at workplaces.

Although the substitution process would be more desirable if undertaken voluntarily by employers, in most cases legal obligations and mandatory requirements define employers' decision to substitute hazardous chemicals.

However, despite the interest in finding a less polluting and hazardous alternative chemical, it becomes impossible to locate a substitute substance that meet the necessary technical parameters.

In other cases, during the search for an alternative substance (following the substitution steps described in paragraph 4.1.2) it is necessary to adopt temporary precautionary measures to avoid or minimize health and environmental damage caused the hazardous substance to be substituted.

In such cases any action taken must be included in the framework of safety measures and procedures to ensure a minimum level health and environmental risks.

When the substitution of a hazardous substance is not feasible, preventive measures must be adopted to ensure safe handling and industrial activity.

Priorities in the implementation of preventive measures are defined by the principles of preventive action.

The **principles of preventive action** are listed in **Directive 89/391/EEC** on the introduction of measures to encourage improvements in the safety and health of workers at work[32]:

Art. 6 The employer shall implement the measures referred to in the first subparagraph of paragraph 1 on the basis of the following general principles of prevention:

a) <u>avoiding risks</u>: the ideal situation implies avoiding or substituting the hazardous substance

b) <u>evaluating the risks which cannot be avoided:</u> whenever substitution is not possible, it becomes necessary to assess the health and environmental risks caused by exposure to the given substance

[32] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1989L0391:20081211:EN:PDF

This obligation is also established by *Art. 12. B of ILO Convention 170 concerning Safety in the use of Chemicals at Work establishing the employers' obligation to assess the exposure of workers to hazardous chemicals.*
Risk assessment can be defined as a matrix of gravity of risks and probabilities of exposure, as described in paragraph 4.3 (identification of hazardous conditions) to determine preventive and control measures.

c) combating risks: at source by adopting technical or administrative measures

d) adapting the work: to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods

e) adapting to technical progress: considering recent results of research carried out by relevant institutions or authorities

f) replacing the dangerous by the non-dangerous or the less dangerous

g) developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment

h) adopting measures that give collective protective measures priority over individual protective measures: a most important principle that suggests measures to eliminate risks at source and only when this is not possible adopting personal protection measures (masks, goggles, gloves)

5.3.1 Procedures for action on chemical risks

Preparing the intervention

It is essential to become familiar with employers' and workers' perceptions and attitudes on chemical risks in the company. Information and awareness measures may be necessary, namely on:

- ✓ existence of chemical risks in the company
- ✓ human and environmental effects of chemical products;
- ✓ possibility of avoiding or reducing risk (less hazardous substances, best practices, etc...)

Identification of risk situations

Risk of environmental exposure may originate in the generation of contaminated solid waste, discharge of hazardous products into the sewage, landfills or accidental leaks/emissions of hazardous substances.

The company could have several workstations where hazardous products/wastes are handled or discharged, included combined discharges of multiple chemical compounds.

Identification of hazardous substances and materials

Identification of such substances implies knowing their persistence, health and environmental effects. The necessary information for identification can be found in products' labels and safety data sheets, as well as in risk assessments and company environmental reports. Once the substances are identified it is necessary to define the type of risk they are associated with.

The process is described in detail in paragraph 3.3 of this section.

Identification of risk

Once hazardous substances and their intrinsic risks have been identified, the next step is to determine the risks associated with the use of substances, (work processes or environmental emissions caused by those processes) i.e. all risk factors, circumstances and conditions of use of substances at the workplace.

Rating and risk assessment

This step entails assessing risks and risk situations in order to define priority actions and measures.

Such assessment must include all the information available on the substance:

- ✓ Properties
- ✓ Characteristics of exposure
- ✓ Conditions of use
- ✓ Health effects caused by exposure
- ✓ Waste generation and uncontrolled emissions, discharges of chemical products
- ✓ Workers' and experts' opinions

Planning performance

Priority intervention and measures must be established. They include:

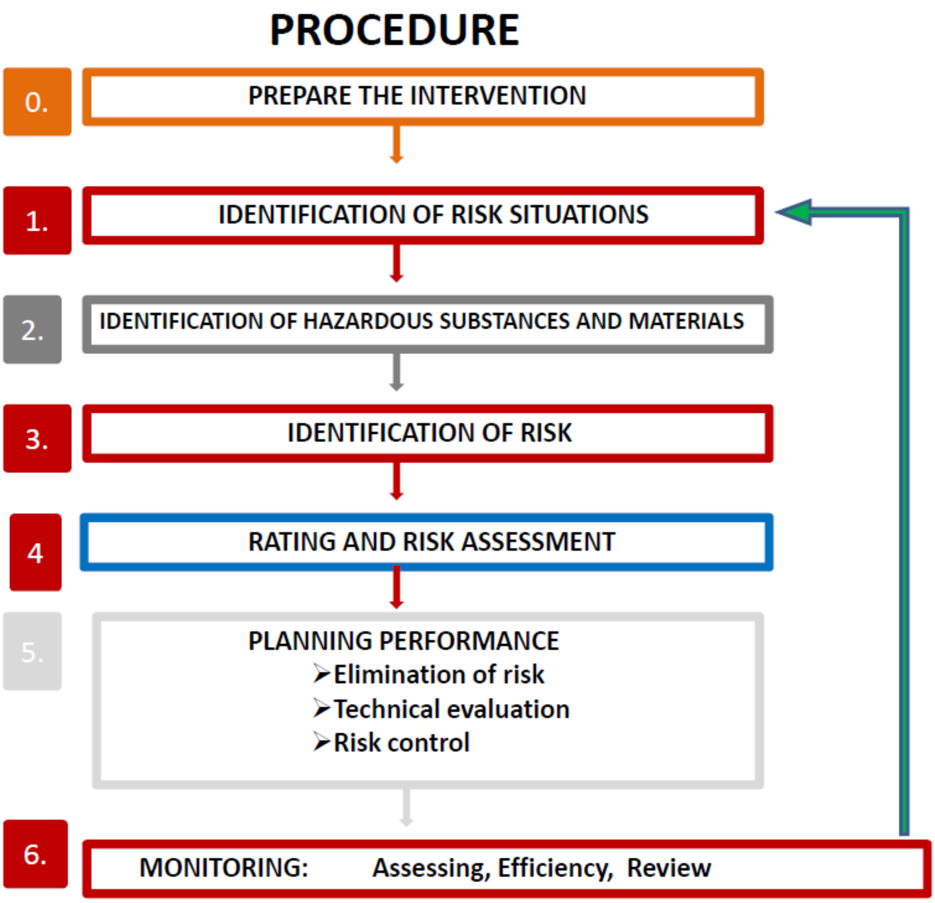
- ✓ Training and information for workers: workers must familiarize with the risks of products and the preventive measures to adopt in each case
- ✓ Control and reduction of exposure through priority preventive measures according the principles previously described and action on the most significant risks
- ✓ Health surveillance measures based on systematic and continuous gathering data on workers' health, as complementary information to risk assessments. The

efficiency of preventive measures must be assessed and results will be analysed and used for the implementation of the company's preventive programme[33]

Monitoring

All preventive measures must undergo a follow-up process to verify their efficiency and correct implementation. It is necessary to corroborate if risk reduction and environmental goals have been achieved, revise and restart the process in case of non-compliance.

Figure 7: Procedures for action on chemical risks



[33] ISTAS. Prevention of chemical risk at the workplace (Available only in Spanish) (http://www.istas.net/web/abreenlace.asp?idenlace=1367

5.4 Case stories of POPs substitution experiences

Substitution of formaldehyde by starch in adhesives used in the manufacture of wood particle boards

Adhesives used in the manufacture of wood particle boards (chipboard) contain, among other hazardous chemicals, formaldehyde (carcinogen and sensitizer). Employees were exposed to high concentrations of formaldehyde during the manufacture of wood particle boards. The union's (CCOO) regional health and safety department in Galicia, Spain, put forward an initiative for the substitution of formaldehyde by starch.

Substitution description

A company that manufactured wooden particle boards used polyester resins that contained formaldehyde among other dangerous elements.

Chipboards are made of small wood shavings pressed with an adhesive at the required temperature. Aminoplast adhesive resins are used during manufacture. Those resins are made up of urea-formol (chipboards) or melamine-formol compounds (damp-proof particle boards). Resins are used as dispersants in the paper, glue and chipboard mix for later plastification.

These resins contain several hazardous substances such as formaldehyde (carcinogen and sensitizer); melamine (possibly human carcinogen, endocrine disruptor, sensitizer and toxic to aquatic organisms); or 2-butoxyethanol (possibly human carcinogen, endocrine disruptors, neurotoxic and is a volatile organic compound (VOC)).

The Galician union's occupational health department had unsuccessfully sought to substitute formaldehyde in companies, due to its harmful health and environmental effects. Health effects of formaldehyde include nasopharyngeal cancer, toxicity by inhalation and asthma aggravation. Hygienic measurements detected formaldehyde concentrations of 1.8mg/m3 (almost 5 times above the occupational exposure limit value), which required the reduction of exposure.

The company was initially reluctant to implement substitution but union representatives insisted on the necessity to replace formaldehyde given the fact that limit values were exceeded and that the chemical would soon be reclassified as category 1carcinogen, which would make substitution compulsory if viable alternatives were available.

The substance most appropriate that the union's occupational health department found to replace formaldehyde at this company was starch.

<u>The substituted substance is Formaldehyde</u>

CAS No. 50-00-0 EC No. 200-001-8 Index No. 605-001-00

Chemical group Aldehyde

Classification: R-phrases

R34 Causes burns; R40 Limited evidence of a carcinogenic effect; R43 May cause sensitization by skin contact; R23/24/25 Toxic by inhalation, in contact with skin and if swallowed. The substance is 1 carcinogen according to IARC (International Agency of Research of Cancer)

Classification: hazard statements

H301 Toxic if swallowed; H311 Toxic in contact with skin; H314 Causes severe skin burns

and eye damage; H317 May cause an allergic skin reaction; H331 Toxic if inhaled; H351

Suspected of causing cancer

Other adverse effects

The alternative substance is Starch (CAS No. 9005-25-8 EC No. 232-679-6)

Chemical group Carbohydrates

Alternative substance has no risks.

Risk assessment:

Formaldehyde is a carcinogen category 1 according to IARC (R40). It is also a sensitizer: may cause sensitization by skin contact (R43). Because of these two important risks, formaldehyde is listed in the hazardous Substance Database according to SUBSPORT Screening Criteria (SDSC).

Formaldehyde is toxic by inhalation, in contact with skin and if swallowed (R23 /24/25)

6. Alternatives assessment

6.1 Define acceptance criteria for alternatives

In the same way we established criteria to identify chemicals of high level of concern, the next step is to determine which alternatives are not acceptable in any case or are preferable. Later during the assessment of alternatives, the hazardous properties of the chemical to be substituted will be compared to the properties of the alternatives we have identified and sifted according to our acceptance criteria.

What are the requirements for a product or technology to be considered a possible alternative? Can intrinsic characteristics be defined for the selection of alternatives?

The next paragraphs explain the development of intrinsic qualities that make a substance or process preferable to others.

The first reference to define ideal qualities in an alternative substance is the description of 12 principles of **green chemistry** developed by Anastas and Warner[34].

According to those principles, safer substances, products or processes must include the following features:

- ✓ Pose little or no toxicity to human health and the environment
- ✓ Reduce or prevent waste
- ✓ Use raw materials or renewable feedstocks
- ✓ Break down naturally (biodegradable)
- ✓ Minimize the potential for accidents (intrinsically safe)

Alternatives must retain these characteristics through their whole life cycle.

The method to select the alternatives of the programme Design for the Environment[35] developed by the US Environmental Protection Agency is based upon these criteria.

Principles of Green Chemistry

1. **Prevent waste:** Design chemical syntheses to prevent waste, leaving no waste to treat or clean

2. **Maximize atom economy:** Design synthetic methods to maximize the incorporation of all materials used in the process into the final product

3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to humans and the environment

4. **Design safer chemicals and products:** Design chemical products to be fully effective, yet have little or no toxicity

[34] Paul T. Anastas y John C. Warner, *Green Chemistry: Theory and Practice*, New York: Oxford University Press, 1998, p 30

[35] Design for the Environment Formulator Program, EPA, USA http://www.epa.gov/dfe/saferingredients.htm

5. **Use safer solvents and auxiliaries:** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals

6. **Increase energy efficiency:** Run chemical reactions at ambient temperature and pressure whenever possible

7. **Use renewable feedstocks:** Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined

8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste

9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once

10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment

11. **Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of by-products

12. **Minimize the potential for accidents:** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment

Technical or organizational alternatives

Often the optimal solution in the elimination of a toxic substance is the use of technical or organizational alternatives to avoid de use of chemicals with the same functional efficiency as the substituted substance or product, e.g.: physical cleaning methods as substitutes to solvents, use of agronomic methods for pest and weed control, or using pests as substitutes to pesticides, etc...Selection criteria would therefore include:

1. Intrinsic characteristics:

- ✓ Low/none human or environmental toxicity
- ✓ Avoiding waste generation
- ✓ Being renewable
- ✓ Being biodegradable
- ✓ Being inherently safe

2. Availability of information on hazardous properties

3. Simple chemical composition

4. Same functional efficiency under technical or organizational measures

However, it is much more frequent to use intrinsic qualities that support the rejection of a substance, product or process, i.e. features that alternatives must not include in any case. Those properties are used to sieve possible alternatives.

Negative criteria are the same used to define dangerous substances in section 4.4.3.

Criteria for the substitution of Persistent Organic Pollutants (POPs)

- ✓ According to the Spanish National Implementation Plan[36] the following criteria are to be met in POPs substitution processes: Availability of information: information on the substance chosen as alternative must be sufficient to eliminate the possibility of unacceptable risks to human health and the environment considering the intended use of the substance.
- ✓ Avoid POPs precursors.
- ✓ Whenever feasible, choose mechanical or physical procedures instead of using of hazardous chemicals: many tasks related to cleaning, stripping, degreasing, cutting, welding, etc. have good mechanical and physical alternatives (scrapping, abrasion, blasting, etc.).
- ✓ Avoid substances and products with similar characteristics to POPs according to criteria of Annex D of the Stockholm Convention: persistence, bioaccumulation, long distance dispersion in the environment and adverse effects.
- ✓ Avoid carcinogens, mutagens, endocrine disruptors, reprotoxicants, neurotoxicants, sensitizers and similar chemicals and compounds of high concern.
- ✓ Choose simple and compatible products over complex mixtures and compounds if there is no information available about the effects of components on human health and the environment considering the intended use.

6.2 Asses and compare alternatives

The assessment of alternative chemicals includes the analysis of their effects on human health and the environment, their effectiveness, economic viability and social impact.

Several methods[37] have been developed to carry out such evaluations but they must be implemented when the substance has been identified, its hazard profile has been

[36] Plan Nacional de Aplicación del Convenio de Estocolmo y del Reglamento 850/2004 sobre Contaminantes Orgánicos Persistentes. Ministerio de Medio Ambiente, 2007. [National Plan to implement Stockholm Convention and Regulation 850/2004, on Persistent Organic Pollutants. Ministry of Environment, Spain, 2007]

[37] Rossi M, Tickner J, Geiser K. Alternatives Assessment Framework. Lowell Center for Sustainable Production, University of Massachusetts Lowell, 2006.

established and safer alternatives for humans and the environment have been sifted. Alternatives assessment methods can be divided into two categories[38]:

- ✓ **Methods that compare data on hazards**: those that examine hazardous properties of chemicals to be compared in a matrix. Users must set their own rules to contrast the different alternatives. Several methods include hazard data and risk indexes for the comparison of chemicals.
  Methods in this category are:
  - **Column Model**
  - **Pollution Prevention Options Analysis System (P2OASys)**
  - **TURI 5 Chemicals Alternatives Assessment Study**
  - **COSHH Essentials**

- ✓ **Sifting methods:** are used to analyze chemicals based on previously prioritized hazards. They include recommendations to stop using chemicals of high level of concern. They also provide tools for decision making on alternatives.
  Methods in this category include:
  - **Green Screen**
  - **Quick Scan**

The strongest limitation for all assessment and comparing tools is the lack of data on hazards for most chemicals in use. Alternatives assessment should be an iterative process, as the outcome of the assessment carried out actually may vary with new data on chemicals' properties.

6.3 The Column Model

Elaborated by the "Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung" (IFA, Institute for Occupational Safety and Health of the German Social Accident Insurance) to provide industry with a practical tool for identification of alternative substances. This is a simplified method to make a preliminary comparison between the risks of the different substances and products and offer a quick judgment on the convenience of substitution. The model is based on 6 columns in which the following hazard categories are described:

- ✓ Acute health hazards
- ✓ Chronic health hazards
- ✓ Fire and explosion hazards
- ✓ Environmental hazards
- ✓ Exposure Potential
- ✓ Process hazards

Columns are divided into cells/boxes that contain the criteria to estimate the level of risk based on risk phrases (R phrases), physical form of the substance, evaporation temperature, German classification of hazards for the aquatic environment and type of process (open, manual, etc.).

Cells/boxes correspond to risk levels, ranked from Negligible to Very high.

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[38] Edwards S, Rossi M, Civil P. Alternatives Assessment for Toxic Use Reduction: A survey of methods and Tools. The Massachusetts Toxic Use Reduction Institute, University of Lowell, 2005.

Users can compare risk levels of the substance in use and the alternatives by placing/ assigning both agents in their respective boxes in the table. The necessary information to use this model can be obtained from Chemical Safety Data Sheets, and information on the process in which the given chemical is used.

Products and substances are compared by columns, i.e. by type of hazard. The acute health hazards and chronic health hazards must be evaluated jointly: products are only assessed for similar hazards. Conditions of product use must be considered.

According to the hazard levels identified by this tool, the preferred substitute will be the one with the lowest hazard level. However, an alternative will hardly have the lowest level in all the hazard endpoints, so users must set their own criteria to decide which alternative is preferable. Users must decide which potential hazards are more relevant for the workplace where the product is used taking into consideration the company's possibilities to control or manage the different hazards. For instance, if an alternative substance has a lower level of toxicity than the product in use, but the environmental hazards are higher, the user must decide whether use conditions in the company allow an adequate control of environmental hazards or not, in order to choose that alternative.

The Columns Model includes criteria for the evaluation of hazards in case of lack of information on toxicity. The method advises against the use of substitutes for which there is no information about skin, toxic, mutagenic or sensitizing effects.

In Annex III levels and type of hazard used by the method can be found.

6.4 Green Screen for Safer Chemicals

The Green Screen for Safer Chemicals, developed by Clean Production Action (CPA), is a hazard-based screening method that is designed to inform decision-makers in businesses, governments and individuals concerned with the risks posed by chemicals and to advance the development of green chemistry. The Green Screen defines four benchmarks on the path to safer chemicals, with each benchmark defining a progressively safer chemical:

- ✓ Benchmark 1: Avoid. Chemicals of high concern.
- ✓ Benchmark 2: Use but search for safer substitutes.
- ✓ Benchmark 3: Use but still opportunity for improvement.
- ✓ Benchmark 4: Safe chemical.

Each benchmark includes a set of hazard criteria - including persistence, bioaccumulation, ecotoxicity, carcinogenicity and reproductive toxicity - that a chemical, along with its known and predicted breakdown products and metabolites, must pass.

Green Screen assesses chemicals on the basis of intrinsic hazards determined by their potential to cause acute or chronic human and environmental effects and on certain physical and chemical characteristics of interest for human health.

For a chemical to improve from benchmark 1 to benchmark 2, it must pass all the criteria of benchmark 1. And so on for going from 2 to 3 and from 3 to 4 all specific criteria must be met. Criteria become progressively more challenging in terms of human and environmental safety. Criteria in benchmark 4 represent the safest chemicals.

Alternative chemicals are compared according to the benchmark they belong to.

This method is only used to assess and compare individual chemicals, not products, processes or alternative technologies. Most suitable for use by policy decisions, chemical formulators and products and articles manufacturers. It is applicable only to chemical hazards and risks.

In Annex IV levels and hazard criteria used by Green Screen method can be found,

7. Cost Assessment

Multiple solutions can be found for the substitution of chemicals in companies.

Possibilities include:

- ✓ employers trying to substitute substances used regularly in their companies, e.g.: painter who uses paints that contain regular solvents and substitutes them by others less harmful to human health and the environment
- ✓ green entrepreneurs whose initiative is to launch new products, distinctive by their innovative approach on products, services or processes with a sustainable design. The initiative includes the substitution of hazardous substances by less harmful alternatives; e.g.: entrepreneur that founds a shoe manufacturing company with more sustainable raw material than traditional companies in this sector (using recycled leather and rubber, adhesives that do not contain persistent organic pollutants, etc.)

Some companies/organizations introduce R&D strategies to update their products, seeking competitive improvement. In many cases such strategies imply the substitution of substances.

It is therefore reasonable to assume that many of the methods used to assess possible substitutes are also applicable to the development of new processes, products or services that may be included in the concept of green entrepreneurship. The emerge of sustainable design and assessment for substitution share significant common features

Cost-benefit analysis and assessment must be taken into account both for substitution and in the selection of raw material or process by the company.

Prevailing employers' views have focused so far on economic and quantitative factors in search of maximum profit in a short-term period. The price of input products becomes the most considered factor without an assessment of associated costs during the whole process.

Often the substitution of chemicals and the adoption of preventive measures are regarded as expenditures and hidden costs behind the lack of preventive (costs of substitution) measures are not taken into count.

Costs associated to lack of preventive measures (substitution) are usually unknown factors, assumed as inevitable expenditures. These costs are underestimated and are not correctly valued since they do not include occupational and environmental damages.

Companies that reject substitution often regard the process as a complex practice with unpredictable financial outcomes, in other words a hardly acceptable choice. This resistance is often conditioned by the lack of information on alternatives and by sheer lack of knowledge of the possible results in terms of efficiency, productivity and competitiveness.

Estimated costs of non-substitution must include occupational and social damages, as well as environmental consequences, intangible costs and values that may not be easily measured with conventional methods.

Qualitative benefits of substitution prove that analysis requires a qualitative approach and conclusions that take into accounts all factors in the process of substitution or in the improvement of working conditions.

Occupational health costs exceed all other costs and do not only imply economic loss.

The European Agency for Health and Safety at work has published Executive summary: *Estimating the cost of accidents and ill health at work*[39]. The document includes nine studies on the costs of non-prevention.

According to this report, *in the EU-27 in 2007, 5,580 accidents at the workplace resulted in death and 2.9 % of the workforce had an accident at work that resulted in more than three days of absence*.

The report draws national and international cost estimates of work-related accidents and health problems due to inadequate planning of preventive activity. The following costs are summarized as the most significant:

- ✓ *Productivity costs: costs related to decreases in output or production*
- ✓ *Healthcare costs: medical costs, including both direct (e.g. pharmaceuticals) and indirect (e.g. caregiver time)*
- ✓ *Quality of life losses: monetary valuation of the decrease in quality of life, such as physical pain and suffering*
- ✓ *Administration costs: costs of administration, for example applying for social security payments or reporting on a workplace accident*
- ✓ *Insurance costs: costs regarding insurance, such as compensation payments and insurance premiums*

This five main cost types are further assessed by the perspective(s) taken, that is, in terms of costs to four stakeholders, namely:

- ✓ *Workers and family: the affected individual and close family or friends who are affected by the injury or illness.*
- ✓ *Employers: the company or organisation for which the affected individual works.*
- ✓ *Government: the relevant public authority regarding, for example, social security payments.*
- ✓ *Society: all stakeholders — the effect on society is the overall impact of an injury or illness, excluding transfers between stakeholders (which cancel out)*[40].

The three basic cost categories that should be included in any cost of poor or non-OSH analysis are healthcare costs (direct), productivity costs (indirect) and quality-of-life losses (intangible). Administrative and insurance costs should be added where possible.

A new corporate perspective implies reconsidering the balance between profit and a set of issues regarding quality and competitiveness related to the control of available

[39]https://osha.europa.eu/en/publications/reports/executive-summary-estimating-the-cost-of-accidents-and-ill-health-at-work

[40] https://osha.europa.eu/en/publications/reports/estimating-the-costs-of-accidents-and-ill-health-at-work

resources and their efficient use, as well as health and environmental effects of alternative products and processes.

There is growing market of customers willing to pay for services and products manufactured with raw material and production processes that imply no harm to human health and the environment, in an industrial activity that respects the rights of each member of the production chain.

In order to assess the economic viability of substitution it is necessary to carry out a cost-benefit assessment and analysis.

7.1 Comparison of Costs

The main goal of cost assessment is to obtain a broad perspective that includes the cost of alternatives. Such assessment must not only consider market costs of baselines and their alternatives, but also finding possible costs of the baselines that were not taken into account initially.

Methods to determine the cost of substitution in a company must be clear and concise.

The comparison of annual costs can be drawn using the following table:

Cost category	Analysed substance	Alternative substance

An example of alternative calculation can be found in Annex V

7.2 Cost Analysis

Cost analyses must include direct and indirect costs associated with the production process regularly carried out, as well as the costs associated to the introduction of e new substance, process or alternative service that will provide significant social and environmental benefits.

The US Environmental Protection Agency's website includes information on how to conduct a comparative cost analysis of a baseline and its substitute. *As a minimum, the cost analysis should identify and compare the direct and indirect costs of the baseline* *and the substitutes. If time and resources permit, data are also collected on future liability costs and less-tangible benefits that occur through the implementation of a substitute*[41].

Resources

The European Chemical Agency (ECHA) published in 2013 the document "Estimating the abatement costs of hazardous chemicals"[42], a review of a study published in 2011 on the development of processes to estimate the cost of abatement through the study of six hazardous substances annexed to the document. Methodological learning points will help Member States and companies that work on restriction dossiers or applications for authorization of substances.

The study concludes that *abatement costing for chemicals is inherently complex*.

The European Environmental Bureau published the document "*Guidelines for defining and documenting data on costs of possible environmental protection measures*"[43]. The information included in the document allows estimates on costs for valid comparisons, as well as guidelines on key issues of data processing. These Guidelines were published *to promote good practice in the documenting and use of data on the costs of possible environmental protection measures in the context of international data comparisons.*

The European Commission's report: "*Integrated Pollution Prevention and Control Reference Document on Economics and Cross-Media Effects*"[44], published in 1996, was developed *to assist in the determination of best available techniques (BAT) under Directive 96/61/EC concerning integrated pollution prevention and control [20, European Commission, 1996]*.

The report defines that: *The concept of BAT under IPPC takes into account the likely cost and benefits of measures as well as the aim to protect the environment taken as a whole to avoid creating a new and more serious environmental problem when solving another. BAT in a general sense is determined by stakeholder groups (technical working groups – TWGs) and is presented in a series of BAT reference documents (BREFs). BAT in BREFs serve as a reference point to assist in the determination of BAT-based permit conditions or for the establishment of general binding rules under Article 9 (8).*

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[41] http://www.epa.gov/dfe/pubs/tools/ctsa/ch7/mod7-3.pdf

[42] http://echa.europa.eu/documents/10162/13580/abatement+costs_report_2013_en.pdf

[43]http://glossary.eea.europa.eu//terminology/sitesearch?term=or+defining+and+documenting+data+on+costs+of+possible+environmental+protection+measures+Management

[44] http://eippcb.jrc.ec.europa.eu/reference/BREF/ecm_bref_0706.pdf

Conclusions

1. The substitution process

- ✓ There are multiples drivers for developing a toxic free business like legislation enforcement, marketing, supply chain requirements, workers and environmental protection, public pressure, costs, among others.
- ✓ There are different stakeholders involved in the substitution processes and each one has their own interests and drivers to carry them out.

2. Green entrepreneurship and Free Toxic Chemicals

- ✓ Green jobs represent important opportunities that bring better quality conditions for workers, less negative impact on health and the environment.
- ✓ Green chemistry is an important alternative for entrepreneurs who are looking for new business opportunities. Green entrepreneurship and sustainable innovation is moving into a golden age with significant business opportunities.
- ✓ One of the main founding principles for green innovation is to prioritize the functionality of compounds rather than duplicating the chemistry. Following the substitution process as defined in 4.1.2.
- ✓ All though green innovations make green sense they must also make business sense and knowing the customer, its processes, understanding cultural and business context and benefits as well as presenting cost calculations showing the substitution gains in financial terms is important in order to achieve successful implementation.

3. Identification of chemicals of high concern

- ✓ A substance's intrinsic risk is the most reliable information that can be used to list substances of high concern. Substances of the highest concern include those that in a long-term cause irreversible health and environmental effects: carcinogenic, mutagenic, toxic, persistent and bioaccumulative, toxic for reproduction, endocrine disruptors, sensitizers, neurotoxicants and those that may cause long term adverse effects in the aquatic environment.
- ✓ Different individual response to toxics, as well as, gender factors or specific sensitivity to toxic substances must be taken into account. We have also to consider that multiple exposures to different substances with long-term health effects is the most common way of chemical exposure.
- ✓ Detecting a substance risk means understanding the relation between their hazardous properties and the conditions of use, handling and disposal which determine the resulting exposure for workers and for the environment

4. How and where to identify alternatives

- ✓ In order to identify alternatives to hazardous chemicals is important to have a wider view and understand what the chemical was used for. If we have a broad view of the role of the substance we may find not only alternative substances, but also alternative processes or even organisational changes that might avoid the need to use chemicals at all.

5. POPs' substitution and safe work procedures

- ✓ When the substitution of a hazardous substance is not feasible, preventive measures must be adopted to ensure safe handling and industrial activity. Priorities in the implementation of preventive measures are defined by the principles of preventive action.

- ✓ It is essential to become familiar with employers' and workers' perceptions and attitudes on chemical risks in the company. Information and awareness measures may be necessary, namely on:

  - Preparing for action
  - Identification of risks situations
  - Identification of hazardous substances and materials
  - Rating and risk assessment
  - Planning performance
  - Monitoring

6. Alternatives assessment

- ✓ Not only chemical alternatives must be considered, often the optimal solution in the elimination of a toxic substance is the use of technical or organizational alternatives to avoid de use of chemicals with the same functional efficiency as the substituted substance or product.

- ✓ The assessment of alternative chemicals includes the analysis of their effects on human health and the environment, their effectiveness, economic viability and social impact.

7. Cost Assessment

- ✓ It´s important to make a proper assessment of costs in seeking greener alternatives. In many cases we find that a more environmentally friendly alternative is also more profitable for the company.

Annex I: Tools to identify chemicals of high concern

List of sources to identify substances of high concern:

1. Screening criteria for substances of very high concern (SVHC)

1.1 According to REACH, article 57, substances of very high concern include substances wich are:

a. Carcinogenic category 1 or 2 in accordance with Directive 67/548/EEC;
b. Mutagenic category 1 or 2 in accordance with Directive 67/548/EEC;
c. Toxic for reproduction category 1 or 2 in accordance with Directive 67/548/EEC;
d. Substances which are persistent, bioaccumulative and toxic in accordance with the criteria set out in Annex XIII of this Regulation;
e. Substances which are very persistent and very bioaccumulative in accordance with the criteria set out in Annex XIII of this Regulation;
f. Substances – such as those having endocrine disrupting properties or those having persistent, bioaccumulative and toxic properties or very persistent and very bioaccumulative properties, which do not fulfill the criteria of points (d) or (e) – for which there is scientific evidence of probable serious effects to human health or the environment which give rise to an equivalent level of concern to those of other substances listed in points (a) to (e) and which are identified on a case-by-case basis in accordance with the procedure set out in Article 59.

2. Criteria for screening substances of concern used by different organisations

Alternative assessment tools that include criteria for screening substances of concern:

2.1 Column Model, IFA (Germany)
2.2 Quick Scan, VROM (Netherlands)
2.3 PRIO, KEMI (Sweden)
2.4 Green Screen for Safer Chemicals version, Clean Production Action (Canada, US)
2.5 Design for the Environment Formulator Program – DfE, EPA (USA)
2.6 Five Chemicals alternatives assessment study, TURI (USA)
2.7 NTP 712 INSHT-National Institute for health and safety at work, (Spain)
2.8 Cradle to Cradle Design Protocol, MBDC (USA-Germany)

Other tools and lists that include criteria for screening substances of concern:

2.9 COSHH Essentials, Health and Safety Executive (UK)
2.10 MAL code system
2.11 National Plan to implement Stockholm Convention and Regulation 850/2004, on Persistent Organic Pollutants, Ministry of Environment (Spain)
2.12 SIN LIST, ChemSec (Sweden)
2.13 SIX-CLASSES, Green Science Policy Institute (USA)
2.13 Trade Union List, European Trade Union Confederation (ETUC)
2.14 ISTAS Black list ISTAS (Spain)
2.15 SC Johnson Greenlist

Annex II: Sources of information to identify alternatives

Websites and databases where it is possible to find alternatives to hazardous chemical substances

- catsub.eu
- cleantool.org
- istas.net/risctox/alternativas (Spanish)
- substitution-cmr.fr (French)
- turi.org

- acc2000.gencat.net/mediamb_tecno
- cleanersolutions.org
- cleanproduction.org
- cprac.org
- epa.gov/dfe
- epa.gov/lean
- iehn.org
- ihobe.net
- infocarquim.insht.es
- irsst.qc.ca/solub
- istas.net/fittema/att
- connect.innovateuk.org
- mass.gov/eea
- noharm.org
- praevention-dp-bgetem.bg-kooperation.de
- pius-info.de
- p2pays.org
- sixclasses.org
- sustainablehospitals.org
- sustainableproduction.org
- umweltschutz-bw.de
- who.int/ifcs

Annex III: The GHS Column Model

1 Risk	2a Acute health hazards (single exposure)	2b Chronic health hazards (repeated exposure)	3 Environmental hazards [1]
very high	• Acutely toxic substances/mixtures, Cat. 1 and 2 **(H300, H310, H330)** • Substances/mixtures that in contact with acids liberate highly toxic gases **(EUH032)**	• Carcinogenic substances/ mixtures, Cat. 1A/1B (AGS: K1, K2, **H350, H350i**) • Carcinogenc activities or processes according to TRGS 906 • Substances/mixtures mutagenic to germ cells, Cat. 1A or 1B (AGS: M1, M2, **H340**)	• Substances/mixtures acutely hazardous to the aquatic environment, Cat. 1 **(H400)** • Substances/mixtures of German Water Hazard Class **WGK 3**
high	• Acutely toxc substances/mixtures, Cat. 3 **(H301, H311, H331)** • Substances/mixtures toxic in contact with eyes **(EUH070)** • Substances/mixtures that in contact with water or acids liberate toxic gases **(EUH029, EUH031)** • Substances/mixtures with specific target organ toxicity (single exposure), Cat. 1: Organ damage **(H370)** • Skin sensitising substances/mixtures **(H317, Sh)** • Substances/mixtures that sensitise the respiratory organs **(H334, Sa)** • Eye-damaging substances/mixtures **(H318)**	• Substances/mixtures toxic to reproduction, Cat. 1A or 1B (AGS: R_E1, R_F1, R_E2, R_F2, **H360, H360F, H360D, H360FD, H360Fd, H360Df**) • Carcinogenic substances/ mixtures, Cat. 2 (AGS: K3, **H351**) • Substances/mixtures mutagenic to germ cells, Cat. 2 (AGS: M3, **H341**) • Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 1: Organ damage **(H372)**	• Substances/mixtures chronically hazardous to the aquatic environment, Cat. 1 **(H410)** • Substances/mixtures chronically hazardous to the aquatic environment, Cat. 2 **(H411)** • Substances hazardous to the ozone layer **(H420)**
medium	• Acutely toxic substances/mixtures, Cat. 4 **(H302, H312, H332)** • Substances/mixtures with specific target organ toxicity (single exposure), Cat. 2: Possible organ damage **(H371)** • Substances corrosive to the skin **(H314, pH ≥ 11,5, pH ≤ 2)** • Substances/mixtures with corrosive effect on respiratory organs **(EUH071)** • Nontoxic gases that can cause suffocation by displacing air (e.g. nitrogen)	• Substances/mixtures toxic to reproduction, Cat. 2 (AGS: R_E3, R_F3, **H361, H361f, H361d, H361fd**) • Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 2: Possible organ damage **(H373)** • Substances/mixtures that can harm babies via their mothers' milk **(H362)**	• Substances/mixtures chronically hazardous to the aquatic environment, Cat. 3 **(H412)** • Substances/mixtures of German Water Hazard Class **WGK 2**
low	• Skin-irritant substances/mixtures **(H315)** • Eye-irritant substances/mixtures **(H319)** • Skin damage when working in moisture • Substances/mixtures with a risk of aspiration **(H304)** • Skin-damaging substances/mixtures **(EUH066)** • Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: irritation of the respiratory organs **(H335)** • Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: drowsiness, dizziness **(H336)**	• Substances chronically harmful in other ways (no H-phrase, but still a hazardous substance!)	• Substances/mixtures chronically hazardous to the aquatic environment, Cat. 4 **(H413)** • Substances/mixtures of German Water Hazard Class **WGK 1**
negligible	• Safe substances on the basis of experience (e.g. water, paraffin and the like)		• Substances/mixtures not hazardous to the aquatic environment **(NWG**, former **WGK 0)**

[1] The water hazard class is only referred to as an assessment criterion for substances/mixtures that have not (yet) been classified in terms of their environmental hazard properties.

4 Physico-chemical hazards (fire, explosion, corrosion et al.) [2] H-phrases marked in blue occur several times.	**5 Hazards from release behaviour**	**6 Process-related hazards**
• Unstable explosive substances/mixtures (**H200**) • Explosive substances/mixtures/products, divisions 1.1 (**H201**), 1.2 (**H202**), 1.3 (**H203**), 1.4 (**H204**), 1.5 (**H205**) and 1.6 (without H-phrase) • Flammable gases, Cat. 1 (**H220**) and Cat. 2 (**H221**) • Flammable liquids, Cat. 1 (**H224**) • Self-reactive substances/mixtures, Types A (**H240**) and B (**H241**) • Organic peroxides, Types A (**H240**) and B (**H241**) • Pyrophoric liquids or solids, Cat. 1 (**H250**) • Substances/mixtures which in contact with water emit flammable gases, Cat. 1 (**H260**) • Oxidising liquids or solids, Cat. 1 (**H271**)	• Gases • Liquids with a vapour pressure › 250 hPa (mbar) (e.g. dichloromethane) • Dust-generating solids • Aerosols	• Open processing • Possibility of direct skin contact • Large-area application • Process index 4 according to TRGS 500 (open design or partially open design, natural ventilation)
• Flammable aerosols, Cat. 1 (**H222**) • Flammable liquids, Cat. 2 (**H225**) • Flammable solids, Cat. 1 (**H228**) • Self-reactive substances/mixtures, Types C and D (**H242**) • Organic peroxides Types C and D (**H242**) • Self-heating substances/mixtures Cat. 1 (**H251**) • Substances/mixtures which in contact with water emit flammable gases, Cat. 2 (**H261**) • Oxidising gases, Cat. 1 (**H270**) • Oxidising liquids or solids, Cat. 2 (**H272**) • Substances/mixtures with certain properties (**EUH001, EUH006, EUH014, EUH018, EUH019, EUH044**)	• Liquids with a vapour pressure 50 ... 250 hPa (mbar) (e.g. methanol)	• Process index 2 according to TRGS 500 (partially open design, process-related opening with simple extraction, open with simple extraction)
• Flammable aerosols, Cat. 2 (**H223**) • Flammable liquids, Cat. 3 (**H226**) • Flammable solids, Cat. 2 (**H228**) • Self-reactive substances/mixtures, Types E and F (**H242**) • Organic peroxides, Types E and F (**H242**) • Self-heating substances/mixtures, Cat. 2 (**H252**) • Substances/mixtures which in contact with water emit flammable gases, Cat. 3 (**H261**) • Oxidising liquids or solids, Cat. 3 (**H272**) • Gases under pressure (**H280, H281**) • Substances/mixtures corrosive to metals (**H290**)	• Liquids with a vapour pressure 10 ... 50 hPa (mbar), with the exception of water (e.g. toluene)	• Closed processing with possibilities of exposure, e.g. during filling, sampling or cleaning • Process index 1 according to TRGS 500 (closed design, tightness not ensured, partially open design with effective extraction)
• Not readily flammable substances/mixtures (flash point › 60 ... 100 °C, no H-phrase) • Self-reactive substances/mixtures, Type G (no H-phrase) • Organic peroxides, Type G (no H-phrase)	• Liquids with a vapour pressure 2 ... 10 hPa (mbar) (e.g. xylene)	• Process index 0,5 according to TRGS 500 (closed design, tightness ensured, partially closed design with integrated extraction, partially open design with highly effective extraction)
• Non-combustible or only not at all readily flammable substances/mixtures (flash point of liquids › 100 °C, no H-phrase)	• Liquids with a vapour pressure ‹ 2 hPa (mbar) (e.g. ethylene glycol) • Non-dust-generating solids	• Process index 0,25 according to TRGS 500

[2] In view of their specific problems, explosive dusts must be tested in individual cases by a skilled person and have not therefore been assigned to a hazard class.

Notes on Evaluating Substitute Substances by the Column Model

Are recommendations already available on substitute substances?

Answering the question of which product has the lower health risk is difficult. Recommendations for a whole series of questions regarding substitute substances can be applied directly, such as:

- Technical rules for Hazardous substances in the 600 series,
- Recommendations "Exposure assessment of the German Social Accident Insurance Institutions",
- LASI-guidelines, series of BAuA
- Product codes, GISCODEs,
- Other industry guidelines.

Procedures

If there are no recommendations available to help you solve your substitute substance problem, the Column Model can help you make a quick comparison of substances and mixtures. To do so, you only need the brief information found in the Material Safety Data Sheet or on the package labelling.

Proceed as follows:

1. Copy the Column Model table once for each product and note each product's name on a different copy.
2. Refer to the Material Safety Data Sheet for the requisite information. There you will find the hazard classes, H-phrases and the German Water Hazard Classes in Chapter 15 of the Material Safety Data Sheet and information on the exposure potential in Chapter 9. You can also find additional information in Chapters 3, 5, 11, and 12.
3. Note the information you find for the respective product on the copy of the Column Model table. Note the procedure used in the last column.
4. Now compare the columns below separately for each product to be evaluated:
   - acute and chronic health hazards
   - environmental hazards
   - physico-chemical hazards
   - hazards from release behaviour
   - hazards caused by procedures

Please bear in mind:

- Comparisons are only to be made within a column, and never within a line. The columns for "acute health hazards" and "chronic health hazards" count as one single column.
- Also mixtures are assessed only on the basis of their labelling with respect to their acute and chronic health hazards.

Interpretation of the results

On the basis of the outcome of the risk assessment, a product must be substituted if it reduces the risk to employees. A risk exists if employees are capable of spatially and temporally encountering a hazard source (hazardous substance). The **hazards** inherent in hazardous substances have to first become effective (e.g. through exposure, fire, explosion) in order to become relevant **risks**.

The columns **2**, **3** and **4** constitute hazards. The columns **5** and **6** are to be interpreted as „hazards becoming effective".

- If the potential substitute product rates better in all five columns than the product in use, the substitution problem is solved.
- It will mostly be the case that the potential substitute product rates better in some columns, but worse in one or two to other columns. This obliges you to assess which potential hazards – in other words, which columns – play a larger role in your particular situation. If, for example, sources of combustion cannot be excluded in your production processes, then the fire and explosion characteristics together with the exposure potential will have the greater weight. If your production methods result in large quantities of waste by-products, then the environmental hazards will be emphasized.
- Minor differences in the hazard classification only justify the introduction of a substitute substance if the data available for the substitute substance is similar in quantity and quality to that of the substance being substituted.
- In the event of opposing reasons, the difference in a single hazard classification may not be sufficient for the introduction of a substitute substance.
- Columns 2 to 4 (hazards) and 5 and 6 (hazards becoming effective) must always be assessed collectively. If, for instance, a potential substitute substance is only a minor hazard according to columns 2 to 4, but the probability of a hazard becoming effective according to columns 5 and 6 is considerably greater, this substance may not be suitable as a substitute substance.
- With the Column Model, mixtures are not assessed on the basis of their components. The practicality of this procedure is obtained at the expense of certain disadvantages resulting, for instance, from the existence of classification boundaries for mixtures.
- For further interpretation of the results refer to TRGS 600 Annex 2.
- Document your decisions in an appropriate manner (e.g. by attaching the copies described above).

Technical remarks

- Explosive substances/mixtures and products with explosive substances: All subclasses of hazard category "Explosive substances/Mixtures/Products with explosive substances" are listed in the "Very high risk" line, as the subclass does not include any gradation of risk on the basis of their intrinsic properties, but subdivides substances, mixtures and products in their packaged form. In their unpackaged state, the risk from the substances/mixtures/products with explosives in subclass 1.5 is in principle the same as that in subclass 1.1. A generally applicable statement on recommended substitutes cannot therefore be made within this hazard class.
- Flammable gases: Categories 1 and 2 of the "Flammable gases" hazard category are listed together in the "Very high risk" line. Flammable gases of Categories 1 and 2 have an explosion range and the same safety measures have to be taken. Unlike flammable liquids, Category 2 flammable gases should not be considered less hazardous, and these substances/mixtures have been given the highest risk classification.

Conditions for Using the Column Model according to TRGS 600

What is the problem?

A supposedly less dangerous product can be more dangerous in reality; yet the concrete hazardous characteristics may not have been tested. For the risk assessment, the Hazardous Substances Ordinance therefore states: "If no test data or suitable sound information are available on the acutely toxic, irritant, skin-sensitizing or mutagenic effect or on the effect due to repeated exposure, the substances or mixtures are to be treated in the risk assessment as hazardous substances with the associated effects." TRGS 600 therefore demands: "The Column Model must only be applied if the manufacturer has assessed the substances or mixtures (in terms of the health risk at least in terms of acute toxicity, skin irritation, irritation of the mucous membranes, mutagenic potential and skin sensitization) on the basis of the available data and experience with reference to any gaps in the data (see Safety Data Sheet, Chapters 9 and 11) and has declared that hazardous properties exceeding those of the classification (particularly in terms of toxicity in the event of repeated application) are not be expected on the basis of this assessment".

What effect does this have on the Column Model?

If the information on required tests is unavailable, whereas the instructions in the Material Safety Data Sheet are conform to the TRGS 600, "Yet, it is the experience of the manufacturer that no hazards are to be expected beyond those on the label", then the Column Model can be applied without exception.

If the Material Safety Data Sheet gives details on none or only a few required tests and if an inquiry with the manufacturer has not yielded any information, then it must be assumed when using the Column Model that the respective characteristics are present.

What does this mean specifically?

1. If no information is available on tests for acute toxicity, then the substance or mixture has to be categorized as a "medium risk" in the column "acute health hazards" (in terms of "acute toxic substances/mixtures, category 4", H302, H312, H332).

2. If no information is available on tests of irritant effects to the skin/mucous membrane, then the substance or mixture has to be categorized at least as a "low risk" in the column "acute health hazards" (in terms of an "skin irritant", H315).

3. If no information is available on tests for mutagenic properties, then the substance or mixture has to be categorized as a "high risk" in the column "chronic health hazards" (in terms of a germ cell mutagenic substance, category 2, H341).

4. If no information is available on tests for skin sensitisation, then the substance or mixture has to be categorized as a "high risk" in the column "acute health hazards" (in terms of a skin sensitizer, category 1, H317).

The most consistent procedure is the one in which those products lacking information with regard to the four basic tests described here are not even considered as potential substitutes, or in which products lacking such information are replaced by others that are backed by studies and tests.

The Legal Basis for Finding Substitutes

The Hazardous Substance Ordinance demands, among other things, the following from the employer:

Article 6 (1) of the Hazardous Substances Ordinance:

When conducting a risk assessment as part of the assessment of working conditions in accordance with Article 5 of the Occupational Safety & Health Act, the employer has to ascertain whether employees are engaged in activities with hazardous substances or whether hazardous substances may arise or be released during such activities. If this is the case, he must assess all the resultant risks to the health and safety of employees from the following points of view: ... 4. Scope for substitution ...

Article 7 (3) of the Hazardous Substances Ordinance:

On the basis of the outcome of the substitution test in accordance with Article 6, Section 1, Sentence 2, Number 4, the employer must give priority to substitution. He must replace hazardous substances or processes with substances, preparations, products or processes that are not hazardous or are less hazardous to the health and safety of employees under the associated conditions of use.

Edited by:
Dr. Thomas Smola
Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA)
Alte Heerstr. 111
53757 Sankt Augustin
Germany
Telefon ++49 (0)2241 231-2743
Fax ++49 (0)2241 231-2234
Internet: www.dguv.de/ifa

With participation of:
Dr. Wolfgang Pflaumbaum (IFA)
Dr. Eberhard Nies (IFA)
Prof. Dr. Herbert Bender (BASF)
Prof. Dr. Anke Kahl
(Bergische Universität Wuppertal)
Dr. Petra Schulte
(BAM Bundesanstalt für Materialforschung und -prüfung)

– November 2011 –

Source: IFA, Institute for Occupational Safety and Health of the German Social Accident Insurance

Annex IV: Green Screen for Safer Chemicals

Green Screen for Safer Chemicals

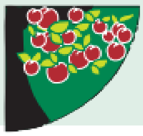
Start at Benchmark 1 (red) and progress to Benchmark 4 (green)

This chemical passes all of the criteria.

BENCHMARK 4

ready biodegradability (low P) + low B + low Human Toxicity + low Ecotoxicity (+ additional ecotoxicity endprints when available)

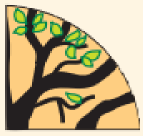
Prefer—Safer Chemical



BENCHMARK 3

a. moderate P or moderate B
b. moderate Ecotoxicity
c. moderate Human Toxicity
d. moderate Flammability or moderate Explosivenesness

Use but Still Opportunity for Improvement



If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 4

BENCHMARK 2

a. moderate P + moderate B + moderate T (moderate Human Toxicity or moderate Ecotoxicity)
b. high P + high B
c. (high P + moderate T) or (high B + moderate T)
d. moderate Human Toxicity for any priority effect or high Human Toxicity
e. high Flammability or high Explosiveness

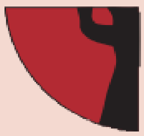
Use but Search for Safer Substitutes

If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 3

BENCHMARK 1

a. PBT: high P + high B + high T[1] (high Human Toxicity[2] or high Ecotoxicity)
b. vPvB: very high P + very high B
c. vPT (vP + high T) or vBT (vB + high T)
d. high Human Toxicity for any priority effect[3]

Avoid—Chemical of High Concern



If this chemical and its break-down products pass all of these criteria, then move on to Benchmark 2

FOOTNOTES:
1 Toxicity – "T" = human toxicity and ecotoxicity
2 Human Toxicity = priority effects (see below) or acute toxicity, immune system or organ effects, sensitization, skin corrosion, or eye damage
3 Priority Effects = carcinogenicity, mutagenicity, reproductive or developmental toxicity, endocrine disruption, or neurotoxicity

ABBREVIATIONS:
B = bioaccumulation **P**=persistence
T=human toxicity and ecotoxicity
vB=very bioaccumulative **vP**=very persistent

Table 1 Threshold Values for Each Chemical Hazard[1] Included in the Green Screen for Safer Chemicals™ Version 1.0

Hazard	Very High (v)	High (H)	Moderate (M)	Low (L)
Environmental Fate				
Persistence - P (half-life in days)[1]	• Soil or sediment >180 days; or • Water >60 days	• Soil, sediment >60 to 180 days; • Water >40 to 60 days; or • Potential for long-range environmental transport	• Soil, sediment 30 to 60 days; or • Water 7 to 40 days	• Soil, sediment <30 days; • Water <7 days; or • Ready bio-degradability
Bioaccumul-ation Potential - B[1]	• BCF/BAF >5000; or • Absent such data, log K_{ow} >5	• BCF/BAF >1000 to 5000; • Absent such data, log K_{ow} >4.5-5; or • Weight of evidence demonstrates bioaccumulation in humans or wildlife	• BCF/BAF 500 to 1000; • Absent such data, log K_{ow} >4-4.5; or • Suggestive evidence of bioaccumulation in humans or wildlife	• BCF/BAF <500; or • Absent such data, log K_{ow} <4
Ecotoxicity				
Acute Aquatic Toxicity[1]		• $LC_{50}/EC_{50}/IC_{50}$ <1 mg/l; or • GHS Category 1	• $LC_{50}/EC_{50}/IC_{50}$ 1-100 mg/l; or • GHS Category 2 or 3	• $LC_{50}/EC_{50}/IC_{50}$ >100 mg/l
Chronic Aquatic Toxicity[1]		• NOEC <0.1 mg/l; or • GHS Category 1	• NOEC 0.1-10 mg/l; or • GHS Category 2, 3 or 4	• NOEC >10 mg/l
Human Health				
Carcinogenicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP known or reasonably anticipated to be human carcinogen; • OSHA carcinogen; • California Prop 65; • IARC Group 1 or 2A; • EU Category 1 or 2; or • GHS Category 1A or 1B	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • IARC Group 2B; • EU Category 3; or • GHS Category 2	• No basis for concern identified or • IARC Group 3 or 4
Mutagenicity/ Genotoxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • EU Category 1 o r 2; or • GHS Category 1A or 1B	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2	No basis for concern identified
Reproductive toxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP Center for the Evaluation of Risks to Human Reproduction; • California Prop 65; • EU Category 1 or 2; or	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Category 3; or • GHS Category 2	No basis for concern identified

[1] *=Priority Human Health Effect. [1]= Experimental data are preferred. Absent experimental data, values based on structure activity relationships are sufficient. **Abbreviations: BAF**=bioaccumulation factor; **BCF**=bioconcentration factor; **EC_{50}**=median effective concentration; **EU**= European Union; **GHS**=Globally Harmonized System of Classification and Labelling of Chemicals; **IARC**=International Agency for Research on Cancer; **IC_{50}**=mean inhibitory concentration; **LC_{50}**=median lethal concentration: the concentration at which 50% of test animals died after exposure; **LD_{50}**=median lethal dose: the dose at which 50% of test animals died during exposure; **log Kow**=log-octanol water partition coefficient; **NOEC**=no observed effect concentration; **NTP**=National Toxicology Program; **OSHA**=Occupation Safety and Health Administration

Hazard	Very High (v)	High (H)	Moderate (M)	Low (L)
		• GHS Category 1A or 1B		
Developmental toxicity*		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • NTP Center for the Evaluation of Risks to Human Reproduction; or • California Prop 65	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Endocrine Disruption*		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates that mechanisms of action lead to adverse effects	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • EU Draft List - Category 1 or 2; or • Japanese list	No basis for concern identified
Neurotoxicity*		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Acute Toxicity (oral, dermal or inhalation)		• LD_{50} <50 mg/kg bodyweight (oral); • LD_{50} <200 mg/kg bodyweight (dermal); • LC_{50} <500 ppm (gas); • LC_{50} <2.0 mg/l (vapor); • LC_{50} <0.5 mg/l (dust or mist); • US EPA Extremely Hazardous Substance List; or • GHS Category 1 or 2	• LD_{50} 50-2000 mg/kg bodyweight (oral); • LD_{50} 200-2000 mg/kg bodyweight (dermal); • LC_{50} 500-5000 ppm (gas); • LC_{50} 2-20 mg/l (vapor); • LC_{50} 0.5-5 mg/l (dust or mist); or • GHS Category 3 or 4	No basis for concern identified
Corrosion/Irritation of the Skin or Eye		• Evidence of irreversible effects in studies of human populations; • Weight of evidence of irreversible effects in animal studies; or • GHS Category 1 (skin or eye)	• Evidence of reversible effects in humans or animals; • GHS Category 2 or 3 — skin irritation; or • GHS Category 2A or 2B — eye	No basis for concern identified
Sensitization of the Skin or Respiratory System		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • GHS Category 1 – (skin or respiratory); or • Positive responses in predictive Human Repeat Insult Patch Tests (HRIPT) (skin)	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Immune System Effects		• Evidence of adverse effects in humans; or • Weight of evidence demonstrates potential for adverse effects in humans	• Suggestive animal studies; • Analog data; or • Chemical class known to produce toxicity	No basis for concern identified
Systemic Toxicity/Organ Effects (via single or repeated exposure)		• Evidence of adverse effects in humans; • Weight of evidence demonstrates potential for adverse effects in humans; • GHS Category 1 — organ/systemic toxicity following single or repeated exposure	• Suggestive animal studies; • Analog data; • Chemical class known to produce toxicity; • GHS Category 2 or 3 single exposure; or • Category 2 repeated exposure	No basis for concern identified
• Physical/Chemical Properties				
Explosive		• GHS Category: Unstable Explosives or Divisions 1.1, 1.2 or 1.3	• GHS Category: Divisions 1.4, 1.5	No basis for concern identified
Flammable		• GHS Category 1 - Flammable Gases; • GHS Category 1 - Flammable Aerosols; or • GHS Category 1 or 2 — Flammable Liquids	• GHS Category 2- Flammable Gases; • GHS Category 2- Flammable Aerosols; or • GHS Category 3 or 4 - Flammable Liquids	No basis for concern identified

Source: Clean Production Action (CPA)

Annex V: Example of an alternative calculation

Annex V is an alternative cost calculation that Paxymer uses during customer meetings in order to widen the definition of material cost. From experience and trials we have seen that even though a kg/kg comparison will show a price increase the total cost at the company may decrease.

Current alt. w Halogens	Yes
Quantity (MT)	10
Fire requirement	EN-61386

	With Paxymer		Current FR	
Marterial	Cost (€/kg)	Dosing (%) 100,0%	Cost (€/kg)	Dosing (%) 100,0%
Base plastic	1,75	82,0%	1,75	88,0%
Flame retardant	8,50	18,0%	13,00	2,0%
Flame retadrant syn.			10,50	10,0%
Additives				
Impact				
Color				
Coupling				
Process add				
UV-stab				
Other				
Material cost	2,97	€/kg	2,85	€/kg
Other cost				
Labour cost*	26,07	€/h	26,07	€/h
Production speed	150	kg/h	150	kg/h
Scrap	1,50%		2,00%	
Waste handling	0	€/kg	0,25	€/kg
Maintenance***	65,78	€/h	66,11	€/h
Machine hourly rate**	5,04	€/h	5,04	€/h
Other cost	0,26	€/kg	0,52	€/kg
Total COGS	3,22	€/kg	3,37	€/kg
Externalities				
Waste°	-	€/kg	0,35	€/kg
Worker safety°°	-	€/kg	0,07	€/kg
Mechanical performance		€/kg		€/kg
Total for product	3,22	€/kg	3,79	€/kg

* Labour cost European average for manufacturing worker. Total cost or employer incl social benefits and fees etc. [2010]
** Electricity and depreciation. Energy is calculated 0,051€/kWh. Machine depreciation over 10 years.
*** assumed 1,5 h of downtime per shift for normal use. 1,25 h for Paxymer.
° Waste Incineration Brief figure for hazardous waste treatment. [2006]
°° 40,1% of workers who are exposed to hazardous environment are affected in a typical year [Eurostat 63/2009]. A number of measures need to be carried out - watch over storage, limiting exposure, controls, measurements etc.

Source: Paxymer®. Numbers are fictional.

Looking at the material cost on the kg/kg comparison (material cost in fig), one finds that Paxymer is at a disadvantage. However after including other costs that are normally included in a cost calculation such as scrap, waste handling, maintenance etc. one will find that Paxymer has a benefit to the competition. Going further and also including

societal cost into the calculation the benefit is further increased in economical terms. Externalities are costs that are carried by the society but are incurred by the company and their decisions.
Going through a calculation at your customers letting the fill in their numbers can provide a strong sales argument if you can show that your product, although more expensive in a kg/kg ratio provides overall savings.

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Regional Activity Centre for Sustainable Consumption and Production (SCP/RAC)

C/ Anglí, 31

08017 Barcelona, Catalonia (Spain)

Tel +34 93 553 87 90 Fax +34 93 553 8795

www.scprac.org

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